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WITTECK DEVELOPMENT INC.

5764

ENERGY CONSERVATION
IN THE INDUSTRIAL MINERALS SECTION
COMMINUTION - PHASE III
D.S.S. FILE NO. 23SQ.23440-4-9263
CCLL CONTRACT NO. 2001P
CANMET SEMINAR
FOR
ACTIVITY NO. 4

MONITORING AND CONTROL OF A DRY GRINDING CIRCUIT USING A PARTICLE SIZE ANALYZER AND PROGRAMMABLE CONTROLLERS

WITTECK DEVELOPMENT INC.

PROJECT NO. 5174

March 24, 1987

WDI

INTRODUCTION

This work forms Phase III of the study on "Energy Conservation in the Industrial Mineral Sector-Comminution" - for Canada Center for Mineral and Energy Technology (CANMET), Energy, Mines and Resources Canada (EMR). Phase I of the programme provided a data base of the direct energy consumed during the comminution of ten industrial minerals. Phase II provided a review of on-stream particle size analyzer.

Witteck Development Inc. of Mississauga, Ontario and I.M.D. Laboratories Ltd. of Toronto, are responsible for Activities 1, 2, 3, 4, 6 & 7 of the Phase III programme. The activities include the following:

Activity 1: Examination of the performance of a "state of the art" high efficiency classifier in a conventional milling circuit.

Activity 2: Examine, study and analyze the state of development of classifiers for cement grinding circuits.

Activity 3: Examine the use of grinding aids and anti-static agents in dry grinding circuits.

Activity 4: Monitoring and control of a dry grinding circuit using a particle size analyzer and programmable controllers.

Activity 6: Evaluate the use of dry autogenous grinding of silica to produce coarse size sand grade product.

Activity 7: Develop the necessary technology to optimize the comminution of mica.

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OBJECTIVES

Optimize the performance of a dry grinding circuit using a "state of the art" high efficiency classifier in a conventional dry milling circuit and on-line measurement of particle size, monitoring production rate, energy consumption and particle size with a personal computer.

The objectives included:

1. Obtain baseline data for the milling circuit using the high efficiency classifier.

2. Complete off-line testing of particle size analyzer in both the wet and dry modes.

3. Develop data to evaluate the operating characteristics, accuracy and repeatability of the analyzer.

4. Operate milling/classification circuit with off-line monitoring of particle size analysis. Adjust classifier conditions and mill feed rate manually.

5. Develop computer software to control milling circuit based on data from particle size analyzer.

6. Control milling circuit using particle size analysis and computer.

7. Monitor and control production and energy consumption while milling circuit is in operation. Operate milling circuit using particle size analysis and computer control.

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ACTIVITY NO. 4

MAJOR EQUIPMENT LIST

1. Hardinge Conical Mill
2. Cyclone Separator
3. Amvest MS-5 High Efficiency Classifier
4. Buffalo Forge MW Size 25 Exhaust Fan
5. Wheelabrator MF Size 9 Cartridge Dust Collector
6. General Electric Two Element Power Meters
7. Individual Ammeters for all Motors
8. Microtrac Particle Size Analyzer
9. Tandy 1000 Personal Computer
10. Micrometrics - Sedigraph 500ET Particle Size Analyzer
11. Miscellaneous Pilot Plant Equipment
12. Optomux Logic Controllers

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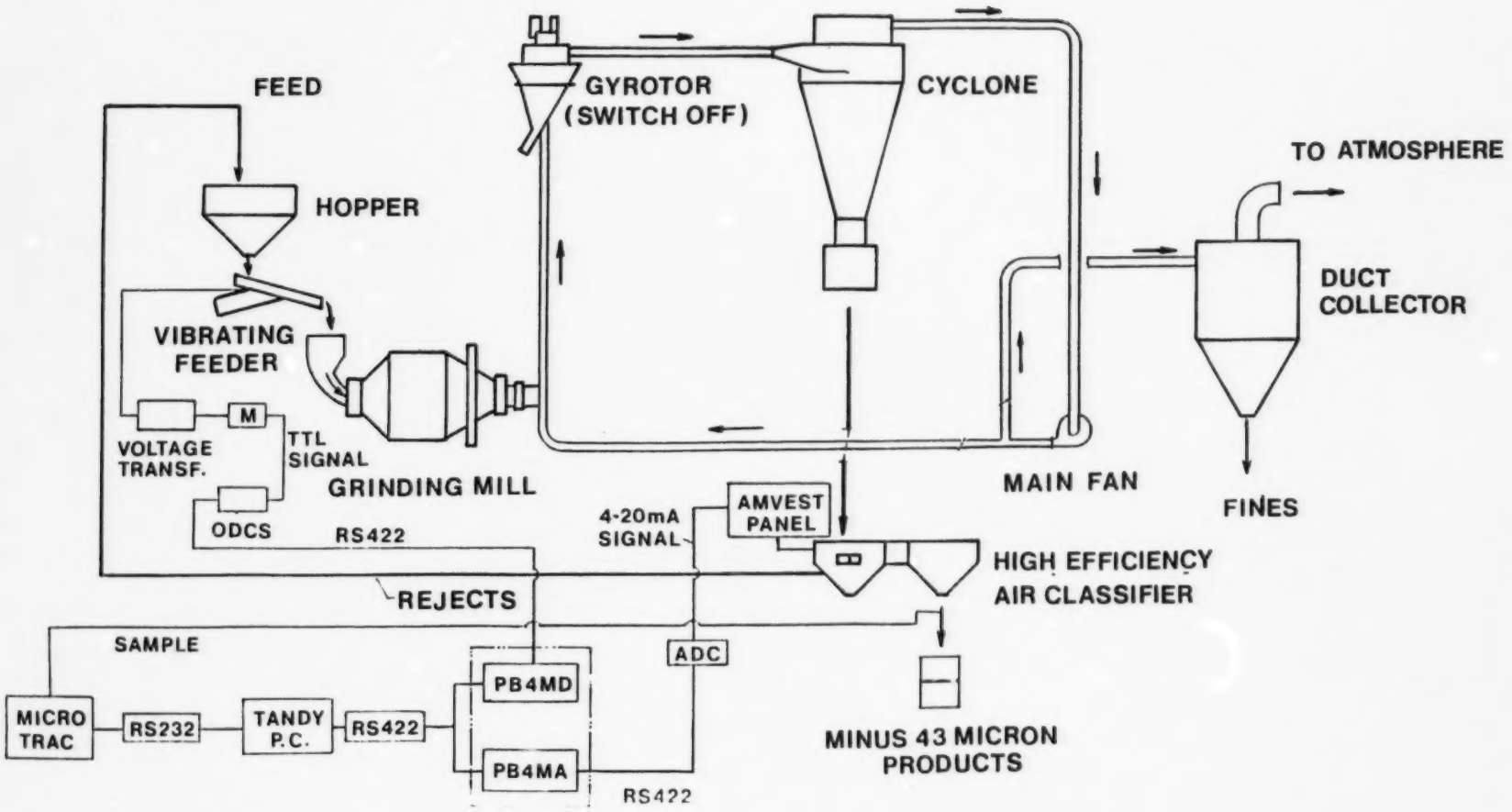
GRINDING/CLASSIFICATION CIRCUIT



CONICAL MILL

MANUFACTURER:	Hardinge (MPSI)
TYPE:	Conical
DIMENSIONS:	4 ft. diameter x 16" long
LINERS:	Nihard
DRIVE:	Winsmith Differential Speed Reducer
	Size 41
	Speed Ratio: 11.9:1
	Reducer is direct coupled to the mill pinion gear
	Mechanical efficiency 91%
MOTOR:	Westinghouse
	25 Horsepower
	1750 rpm
	575 volts/3 phase/60 hz
MILL SPEED:	31 rpm
CRITICAL SPEED:	81%

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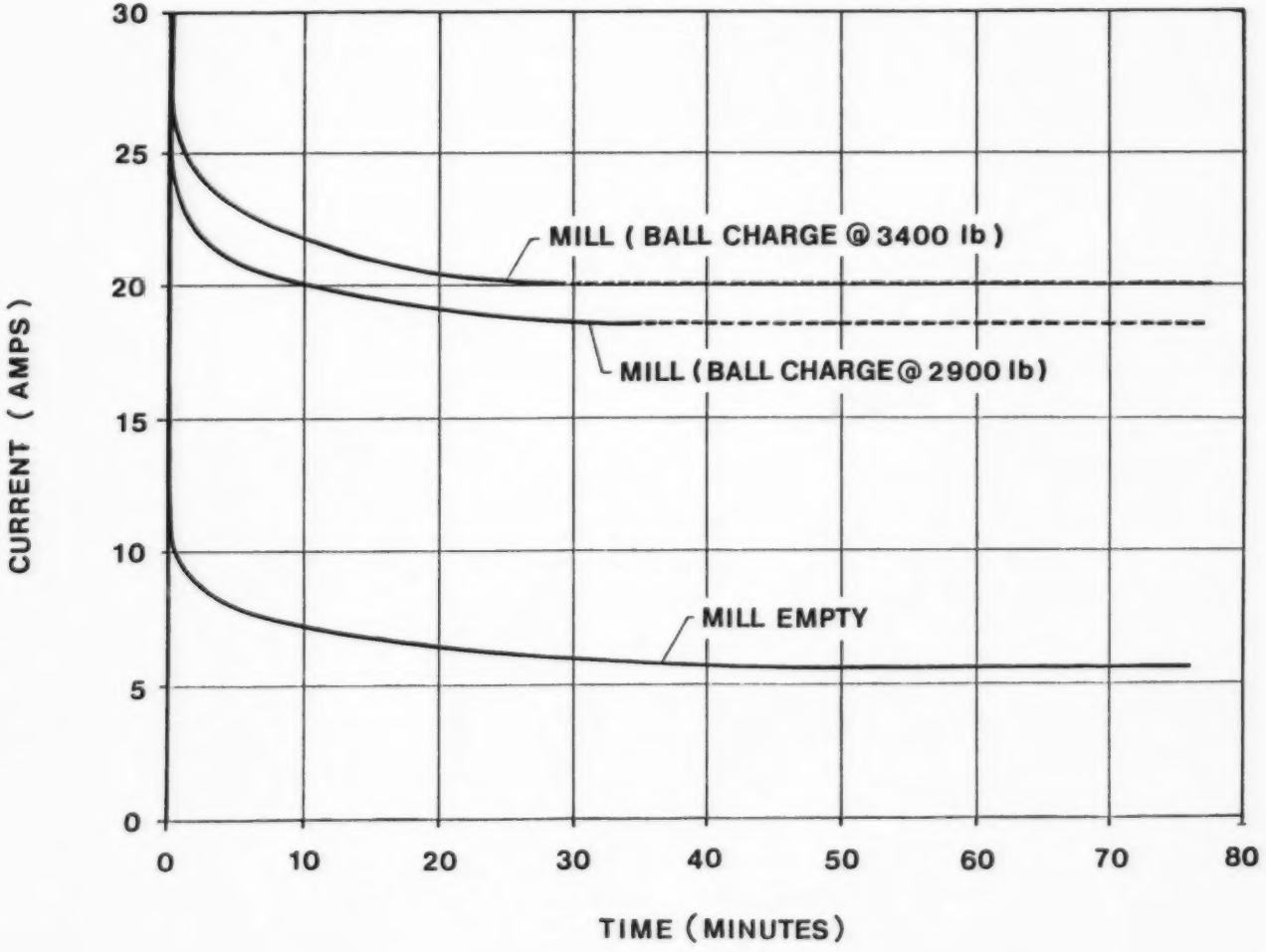
BASELINE CURRENT MEASUREMENTS

MILL CURRENT (AMPS) Vs. TIME (MINUTES)



CONVENTIONAL CLASSIFIER

MANUFACTURER:	Hardinge (MPSI)
TYPE:	Gyrotor
SIZE:	3 ft. diameter
NUMBER OF ROTOR BLADES:	12
MAXIMUM ROTOR SPEED:	350 rpm
MAXIMUM TIP SPEED:	3300 fpm
AVERAGE PRESSURE DIFFERENTIAL:	0.5" W.C.

VARIABLE SPEED DRIVE

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CYCLONE SEPARATOR

SIZE:	5 ft. diameter
CAPACITY:	2000 ACFM
INLET AREA:	0.457 square feet
AVERAGE INLET VELOCITY:	3500 fpm
AVERAGE PRESSURE DROP ACROSS SEPARATOR:	3" W.C.
AVERAGE OPERATING AIR FLOW RATE:	1600 ACFM @ 100^{0} Fahrenheit

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HIGH EFFICIENCY CLASSIFIER

MANUFACTURER: Amvest Progressive Industries Ltd.
Sylacagua, Alabama, U.S.A.

MODEL: MS-5

FEATURES:

- High efficiency classifier
- Complete Pilot Plant set-up
- Self-contained control panel
- Reliable in operation
- Separation at 5 microns
- Variable speed drive on all motors
- Feed controlled by rotary air locks
- Product & reject ports with rotary air locks
- Internal Fan
- Collects its own fines

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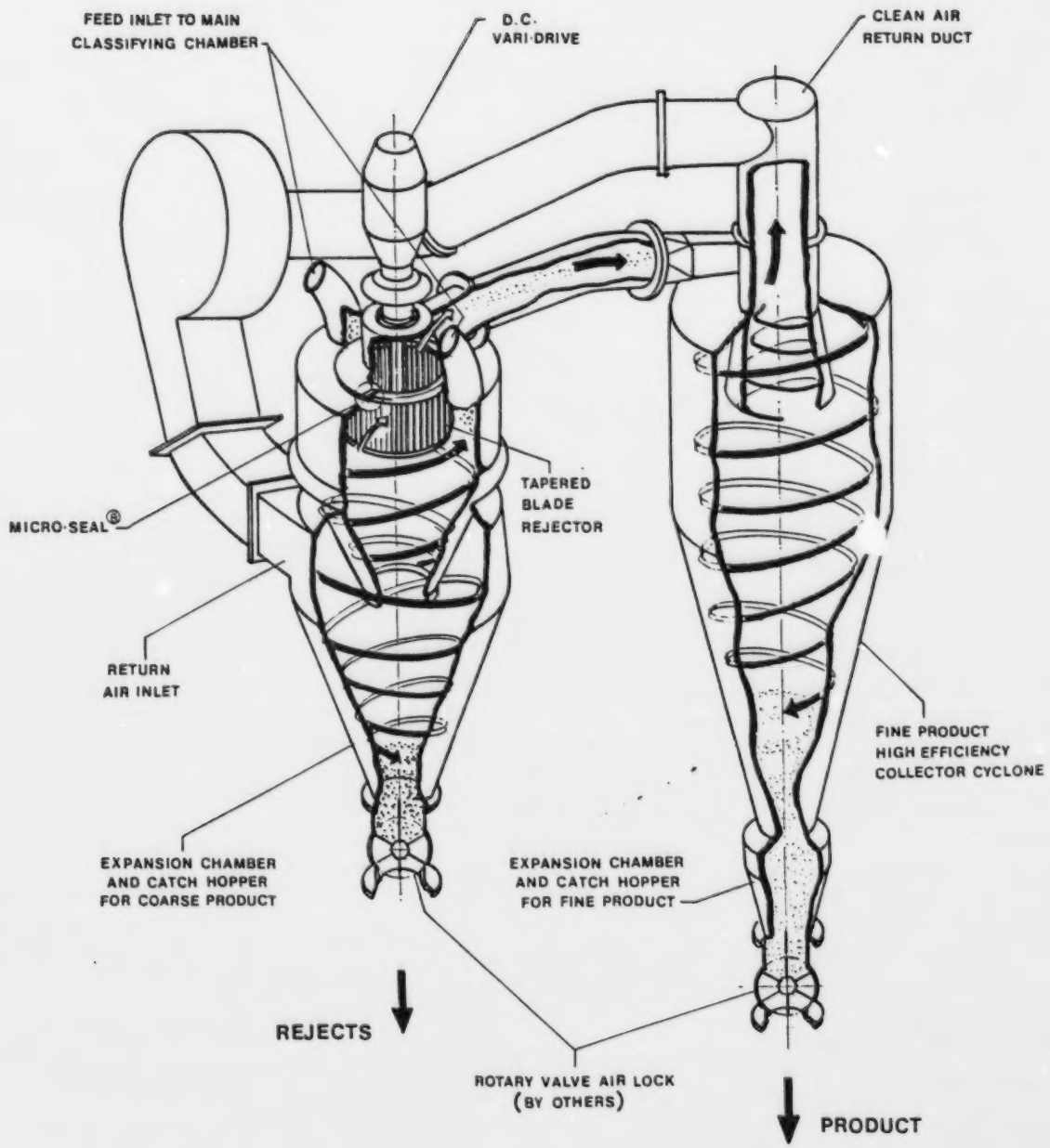
AMVEST-MS 5 CLASSIFIER
INSIDE THE MICRO-SIZER


FEED INLET TO MAIN CLASSIFYING CHAMBER
D.C. VARI-DRIVE
CLEAN AIR RETURN DUCT
TAPERED BLADE REJECTOR
MICRO-SEAL®
RETURN AIR INLET
FINE PRODUCT HIGH EFFICIENCY COLLECTOR CYCLONE
EXPANSION CHAMBER AND CATCH HOPPER FOR COARSE PRODUCT
EXPANSION CHAMBER AND CATCH HOPPER FOR FINE PRODUCT
REJECTS
ROTARY VALVE AIR LOCK (BY OTHERS)
PRODUCT

DUST COLLECTOR

MANUFACTURER:	Wheelabrator Corporation of Canada Ltd.
TYPE:	Cartridge Filter
MODEL NO:	33
NUMBER OF CARTRIDGES:	9
FILTRATION AREA:	1854 Square Feet
AVERAGE CAPACITY:	4500 ACFM
AVERAGE PRESSURE DROP:	6" W.C.

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MAIN EXHAUST FAN

MANUFACTURER:	Canadian Blower (Buffalo)
MODEL:	25 M.W., designed for granular materials
ARRANGEMENT:	No. 9, bottom horizontal discharge
FAN WHEEL DIAMETER:	17 1/2"
OUTLET AREA:	0.565 Square Feet
INLET AREA:	0.615 Square Feet
BEARINGS:	SKF, heavy duty
CAPACITY:	3400 ACFM, @ 17" W.C.
DRIVE:	3 "B" Section Belts
FAN WHEEL SPEED:	3165 rpm
MOTOR:	20 horsepower
	3600 rpm
	575 volts/3 phase/60 hz

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MICROTRAC PARTICLE SIZE ANALYZER

MANUFACTURER:	LEEDS AND NORTHRUP, LARGO FLORIDA
MODEL:	7991-0;
MEASUREMENT RANGE:	1.9 to 176 MICRONS
MEASUREMENT TIME:	3 to 800 SECONDS
SAMPLE REQUIREMENTS:	1.0 to 10.0 GRAMS
SAMPLE TYPE:	SLURRY OR DRY
SAMPLE PATH LENGTH:	1.5 mm
WATER SUPPLY:	POTABLE TAP WATER
	- MINIMUM 5 USGPM
	- 1/2" NPTF CONNECTION
DRAIN:	GRAVITY TO FLOW DRAIN
POWER REQUIREMENTS	117/1/60, 1500 WATTS
DATA PRESENTATION	DIGITAL STRIP CHART
	RS 232C OUTPUT FOR REMOTE DATA
	PRESENTATION

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PERSONAL COMPUTER

COMPUTER MANUFACTURER:	Tandy
MODEL:	1000
DISKETTE SYSTEM:	5 1/4" MS/DOS 1 Drive
MEMORY:	364K
MONITOR:	9" B/W
COMMUNICATIONS:	Port 1 - RS 232
	Port 2 - RS 422

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CONTROLLERS

MANUFACTURER: OPTO 22

TYPE: OTPMUX

MODEL: PB4MA

Analog Mounting Rack

Communicates with most computers via an RS 422 serial communications link.

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DIGITAL CONTROL

MODEL:	CDC 5
LINE VOLTAGE (Max):	60 volts
OPERATING VOLTAGE RANGE:	5-60 VDC
CURRENT RATING:	
45°C:	3 amps
20°C:	2 amps
1 SECOND SURGE:	5 amps
OUTLET VOLTAGE DROP:	1.6 mgc
CONTROL PICK-UP VOLTAGE:	2.5 VDC
CONTROL DROP OVER VOLTAGE:	1 VDC
CONTROL RESISTANCE:	220 ohms
TURN-ON TIME:	100 microseconds
TURN-OFF TIME:	250 microseconds

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ANALOG CONTROL

MODEL:	DA 3
OUTPUT RANGE:	4-20 ma
INPUT:	12 bits serial data
ACCURACY:	1.1% of span
SETTLING TIME TO .1% ACCURACY: (FULL SCALE STEP)	3 milliseconds typical

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PARTICLE SIZE ANALYZER

MANUFACTURER:	Micrometrics
MODEL:	Sedigraph 5000 ET
PARTICLE SIZE RANGE:	0.1 to 100 microns
SAMPLE VOLUME:	25 to 250 cubic centimeters
PARTICLE CONCENTRATION:	0.5 to 5.0 volume percent
X-RAYS:	10,000 eV, 1.25 Angstrom Wave Length
REPRODUCIBILITY:	$\pm$1% for particles greater than 1 micron
	$\pm$3% for particles between 0.5 to 1 micron
	$\pm$5% for particles below 0.5 micron
ACCURACY:	$\pm$1%, provided liquid and solids densities are known and materials are at proper temperature.

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POWER METERS

MANUFACTURER:	Canadian General Electric
MODEL:	V62S
CATALOGUE NO:	102009
AMPERAGE:	One 200 amp
	Two 100 amp
POWER:	600 volts/3 phase/60 hz
NUMBER OF DIALS:	4
MULTIPLIER:	10
NUMBER OF ELEMENTS:	2

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ACTIVITY 1

FEED MATERIAL SPECIFICATIONS

STEEP ROCK CALCITE

SNOWHITE 6-12

Chemical Composition (Typical)

$CaCo_3$	94%
$MgCo_3$	1.8
Fe_2C_3	0.10
Alumina (Al_2C_3)	0.1
Silica	0.8
Silicates	3
Moisture (H_2C)	0.1

Screen Analysis (Typical)

6 mesh	1.5
16 mesh	75.0
30 mesh	97.0
Pan	3

Physical Properites

Dry Brightness (Green Filter)	80
Hardness (MOH's Scale)	3
Specific Gravity	2.71
Bulk Density (gm/liter)	1470
(lb/ft^3)	92

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BASELINE MILL RUNS

Ten baseline mill runs were performed to determine the control parameters and limitations for the Microtrac Analyzer. Statistical data from these runs were used to develop "correction factors" for Microtrac Analysis and control. A plot of these factors versus particle size is shown in the following figure. Parameters of the ten baseline runs are as follows:

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BASELINE RUNS

Test Duration: 3 hours

Classifier Fan Speed: 4,400 r.p.m.

Test No.	Feed Rate (lb/hr)	Rotor Speed (RPM)	Product		
			D_{90}	D_{50}	D_{10}
1	400	800	30	10	1.4
2	400	675	29	11	1.2
3	550	700	29	11.5	1.5
4	550	500	39	15.5	1.6
5	750	750	26	10.5	1.45
6	750	750	28	10.5	1.6
7	800	550	38	14	1.1
8	800	750	26	10	1.2
9	900	550	31	12	1.6
10	900	575	36	14.5	1.8

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COMPUTER CONTROLLED CLASSIFIER TESTS

TYPICAL DEPENDENT VARIABLES

Pressure Difference (in W.G.)

- Fan 16.8"
- Aspirator 4.6"
- Cyclone 1.4"

Static Pressure (in W.G.)

- Fan Intake -6.8"
- Fan Outlet 10.1"
- Uptake -5.6"
- Cyclone Inlet -4.8"
- Cyclone Outlet -6.7"
- Dust Collector -6.7"

Current Measurements (amps)

- Fan 7.8
- Mill 18/19
- Classifier 8/9

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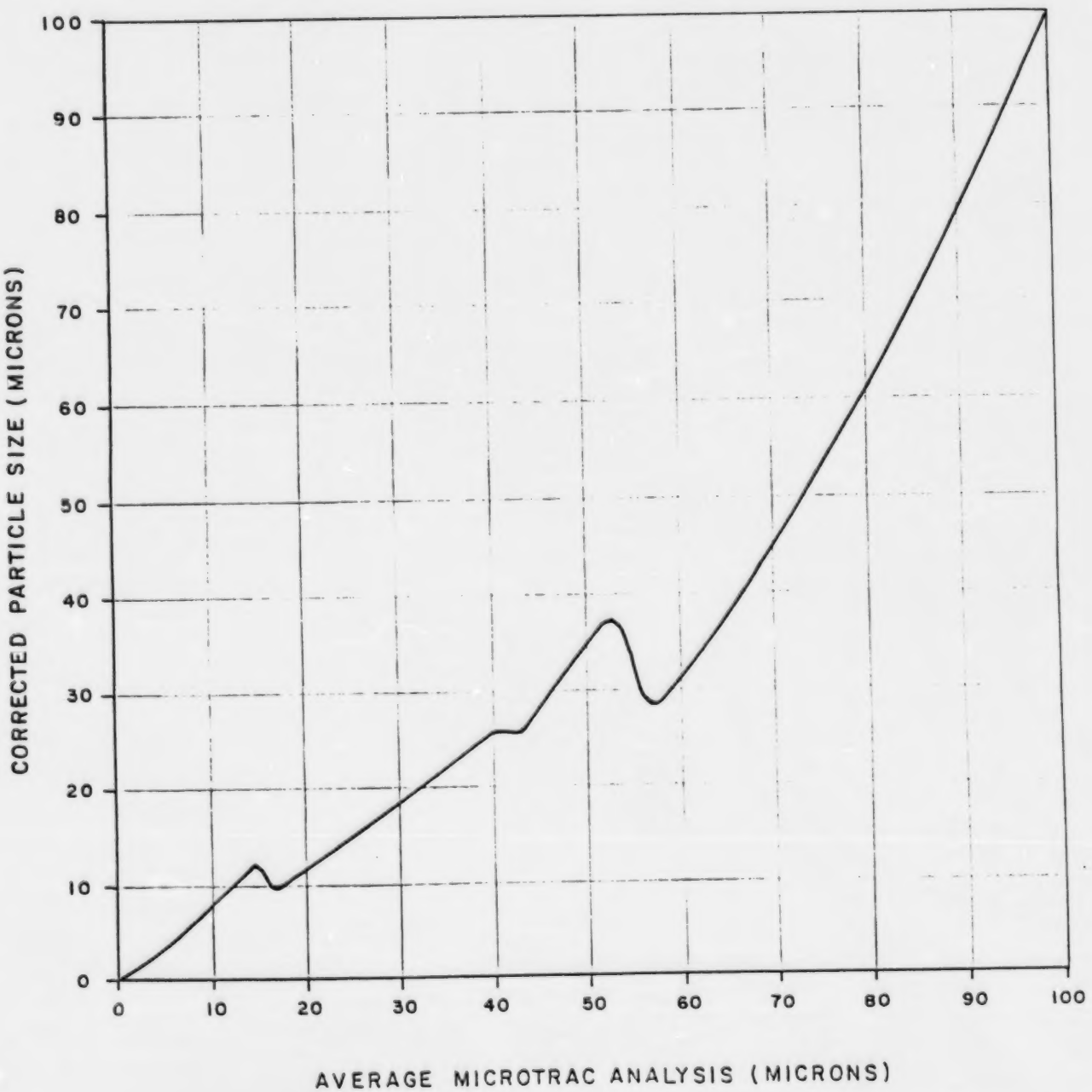
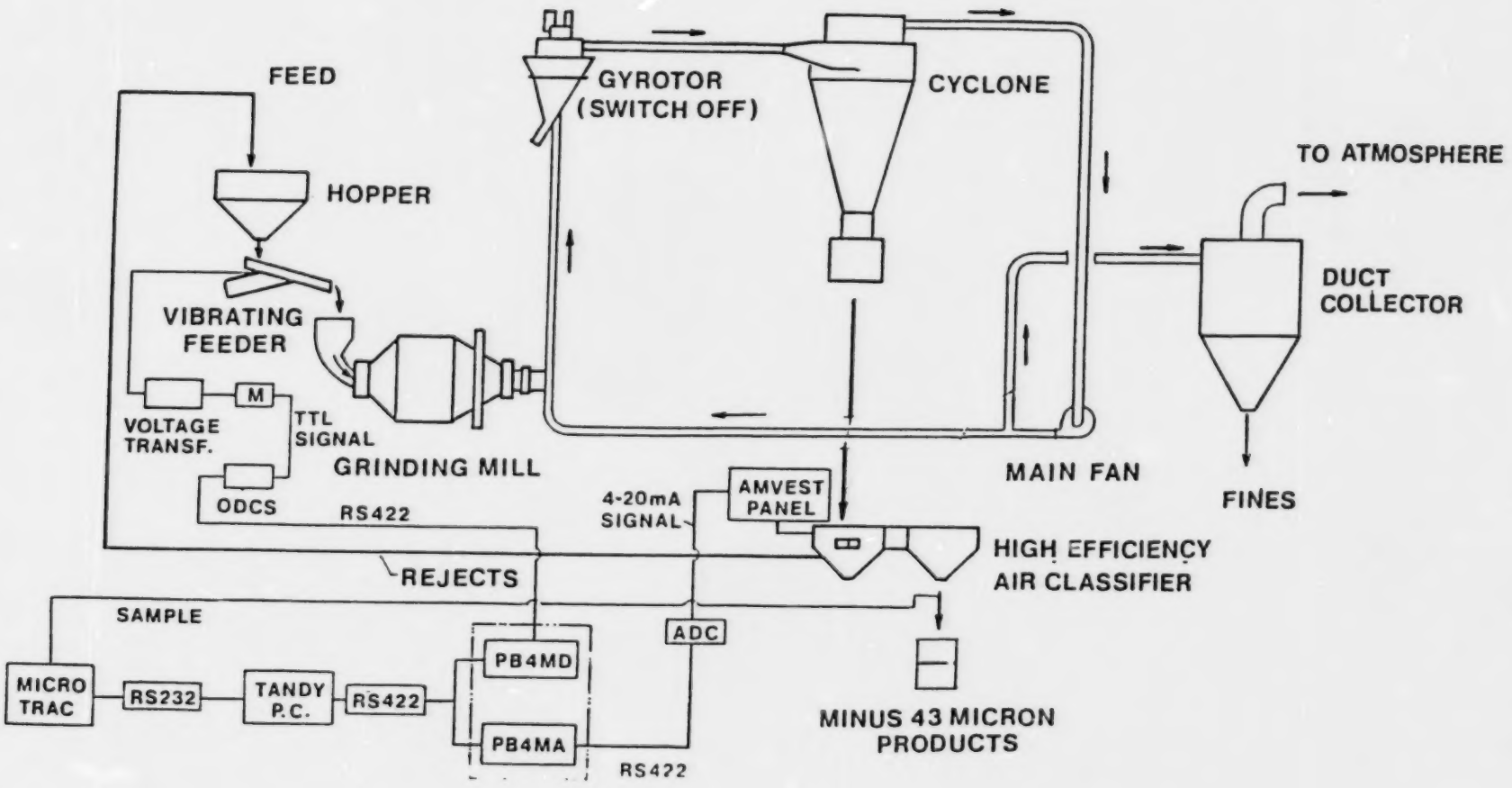
WITTECK DEVELOPMENT INC. – PROJECT 5174

D.S.S. – CANADA CEMENT LAFARGE LTD
ENERGY CONSERVATION IN THE INDUSTRIAL
MINERALS SECTOR – COMMINUTION – ACTIVITY 4

CORRECTION FACTORS FOR MICROTRAC ANALYSIS AND CONTROL



GRINDING/CLASSIFICATION CIRCUIT



RUN NO. 1

Duration: 3 hours 30 minutes

Feed Rate: 750 lb/hr.

Computer Shakedown test. Samples taken every 12 minutes for microtrac analysis. Manual control of circuit based on data generated by computer.

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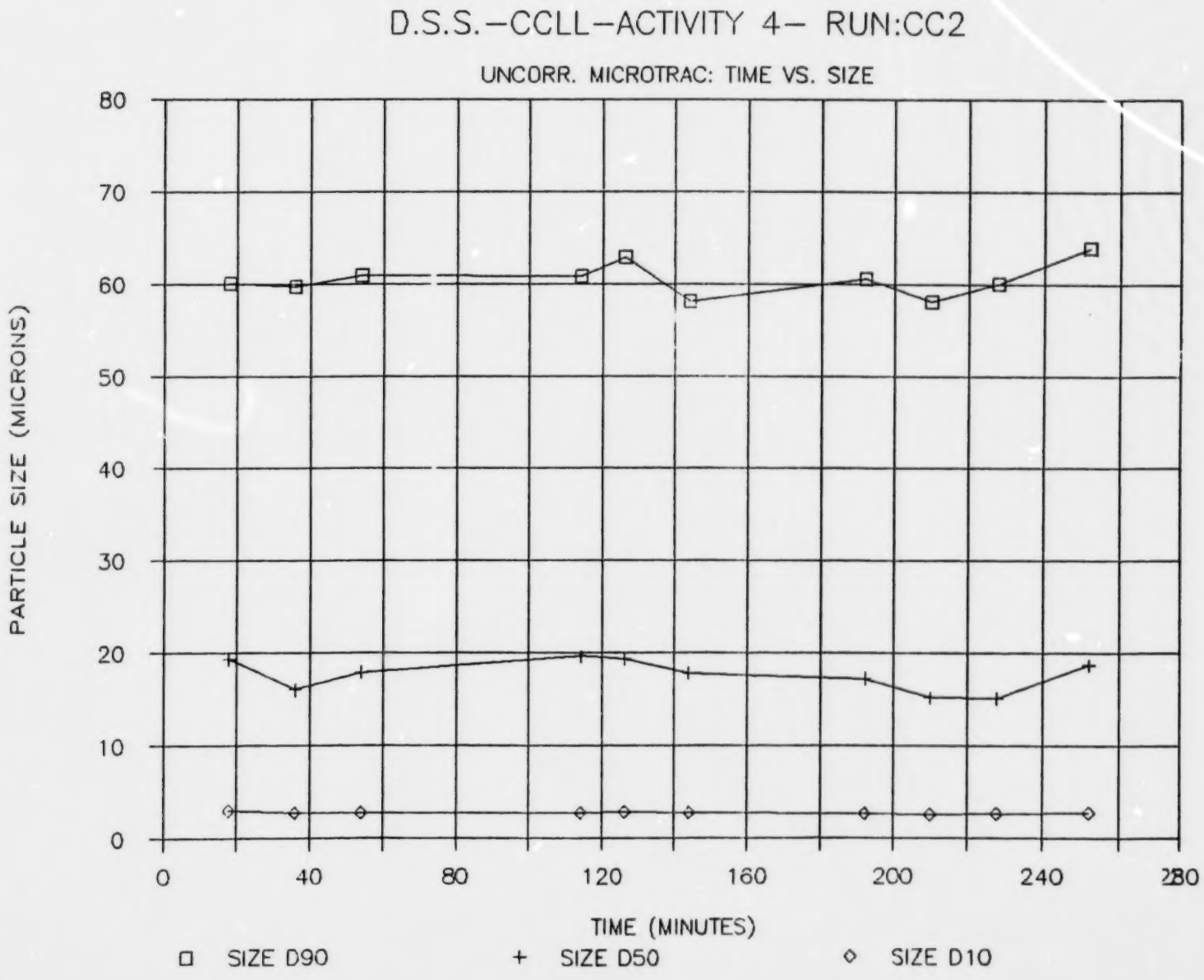
RUN NO. 2

Duration	5 hours
Feed Rate:	550 lb/hr. for 1 hour 30 minutes
	600 lb/hr. for 4 hours
D_{90} Target Size:	D_{90} @ 60 microns.
Control of Circuit:	Manual
Sampling:	Every 12 minutes

Rotor speed of Classifier adjusted manually as per computer generated data to maintain constant D_{90} of product.


D.S.S.–CCLL–ACTIVITY 4– RUN:CC2
UNCORR. MICROTRAC: TIME VS. SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
20
10
0
0
40
80
120
160
200
240
280
TIME (MINUTES)
SIZE D90
SIZE D50
SIZE D10

RUN NO. 3

Duration:	4 hrs 18 minutes
Feed Rate:	750 lbs/hr for 3 hours
	600 lbs/hr for 1 hour 18 minutes
D_{90} Target Size:	100% passing 70 microns
	100% passing 60 microns
Control of Circuit:	Manual
Sampling:	Every 12 minutes after circuit stabilized.

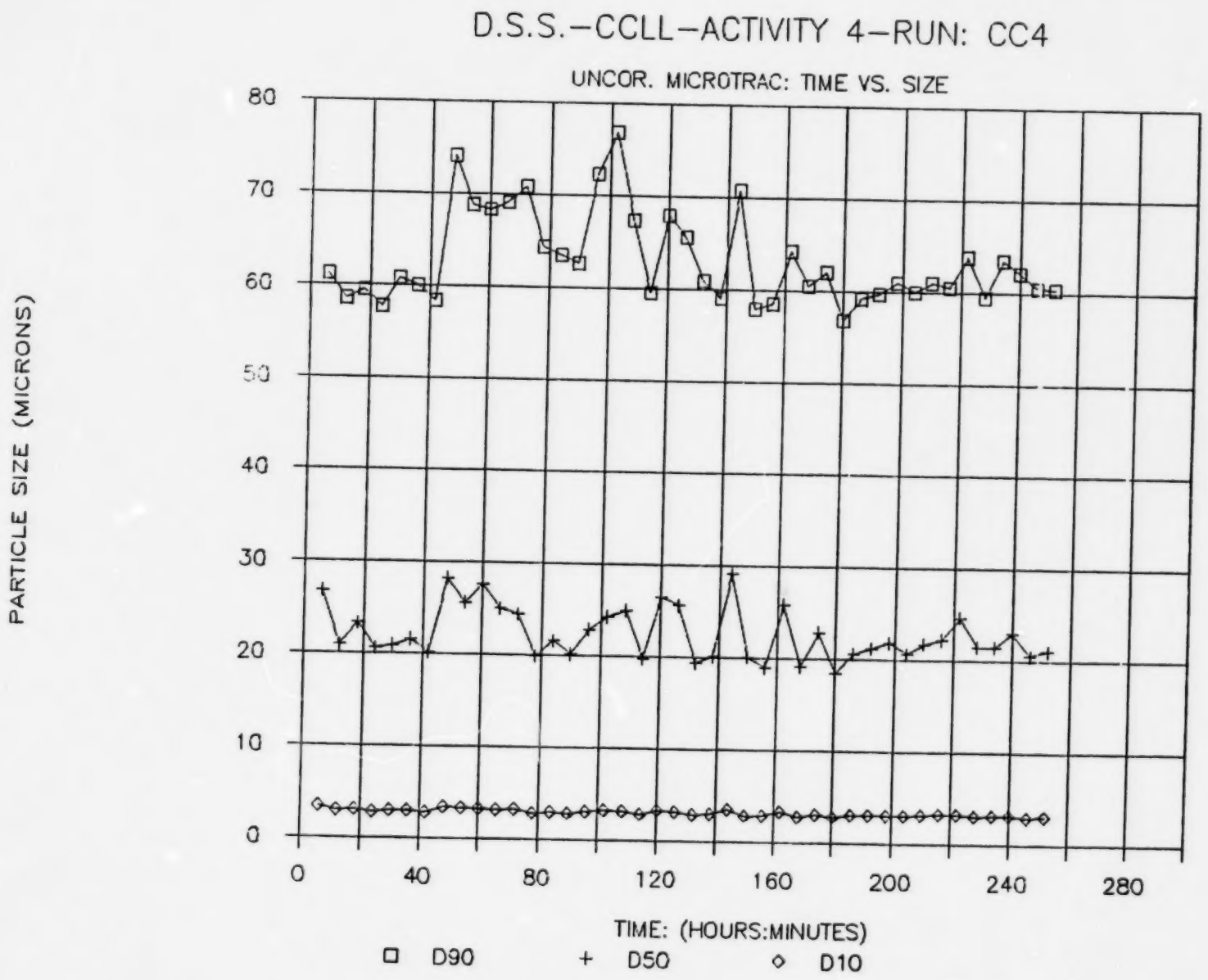
Continuation of test 2 with increased feed rate and rotor speed adjusted to maintain D_{90} target size, as per computer generated data.

RUN NO. 4

Duration:	4 hrs 30 minutes
Feed Rate:	750 lbs/hr for 48 minutes
	800 lbs/hr for 30 minutes
	850 lbs/hr for 30 minutes
	900 lbs/hr for 30 minutes
	1000 lbs/hr for 2 hr. 12 minutes
D_{90} Target Size:	100% passing 70 microns
	100% passing 60 microns
Control of Circuit:	Manual for 2 hr. 40 minutes. Computer controlled for remainder of test.
Sampling:	Every 6 minutes

Feed rate increased gradually to 1000 lbs/hr and circuit allowed to stabilize. Rotor speed adjusted manually as per computer generated data, then full control of circuit brought under computer control. This resulted in much tighter control of D_{90} product size.

WD1

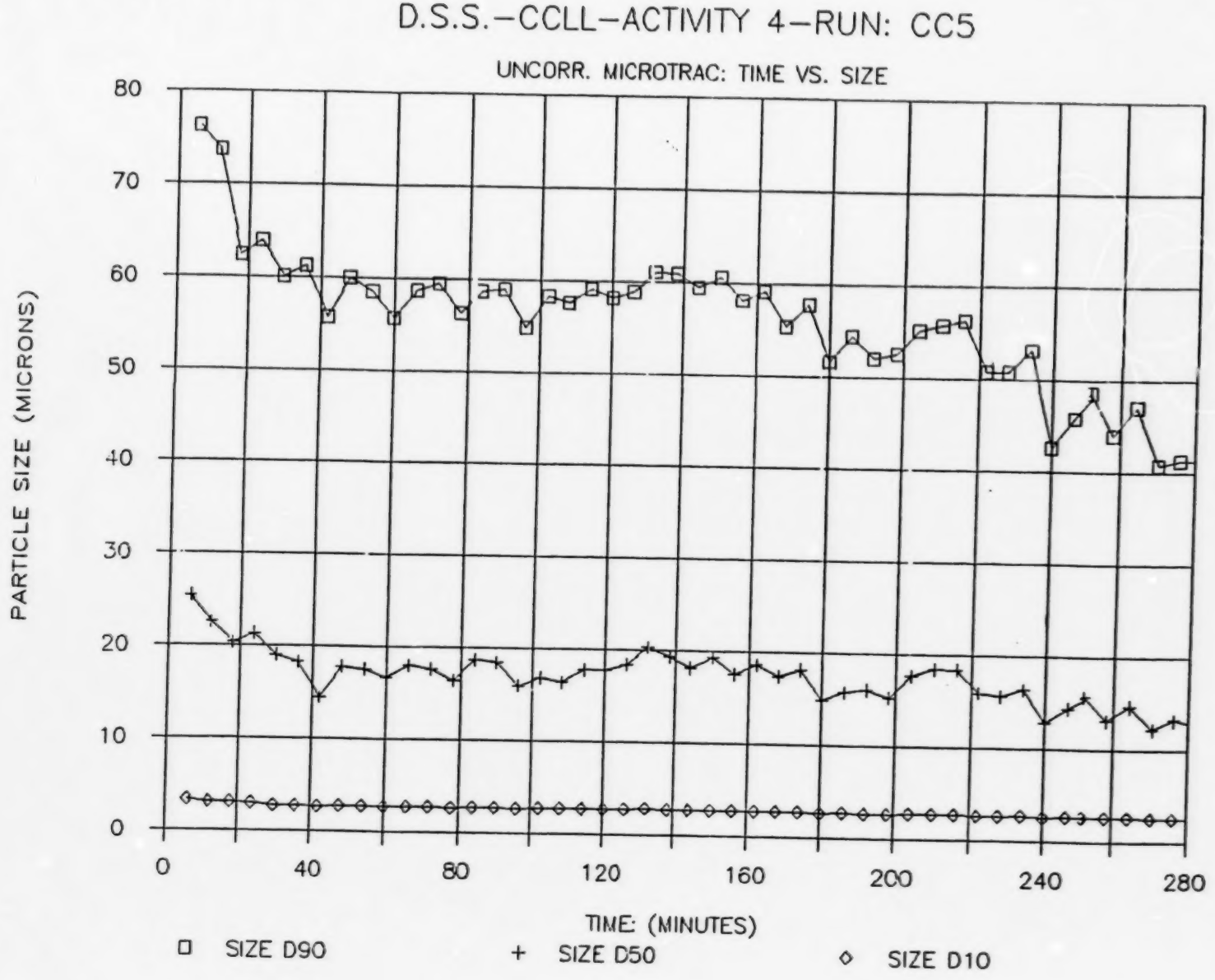

D.S.S.–CCLL–ACTIVITY 4–RUN: CC4
UNCOR. MICROTRAC: TIME VS. SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
20
10
0
0
40
80
120
160
200
240
280
TIME: (HOURS:MINUTES)
D90
D50
D10

RUN NO. 5

Duration:	5 hours
Feed Rate:	850 lbs/hr
D_{90} Target Size:	D_{90} @ 60 microns
	D_{90} @ 50 microns
	D_{90} @ 40 microns
Control of Circuit:	Computer
Sampling:	Every 6 minutes

Feed rate kept constant at 850 lbs/hr, but rotor speed of classifier adjusted from 550 rpm to 650 rpm to determine time required for circuit to balance for a new product specification.

WD1


D.S.S.–CCLL–ACTIVITY 4–RUN: CC5
UNCORR. MICROTRAC: TIME VS. SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
20
10
0
0
40
80
120
160
200
240
280
TIME: (MINUTES)
SIZE D90
SIZE D50
SIZE D10

RUN NO. 6

Duration:	4 hrs 36 minutes
Feed Rate:	850 lbs/hr
D_{90} Target Size:	D_{90} @ 40 microns
	D_{90} @ 30 microns
	D_{90} @ 40 microns
Control of Circuit:	Computer
Sampling:	Every 6 minutes

Rotor speed increased from 758 rpm to 850 rpm and response time of the circuit to readjust and balance was observed. Rotor speed was then returned to 750 rpm for remainder of the test.

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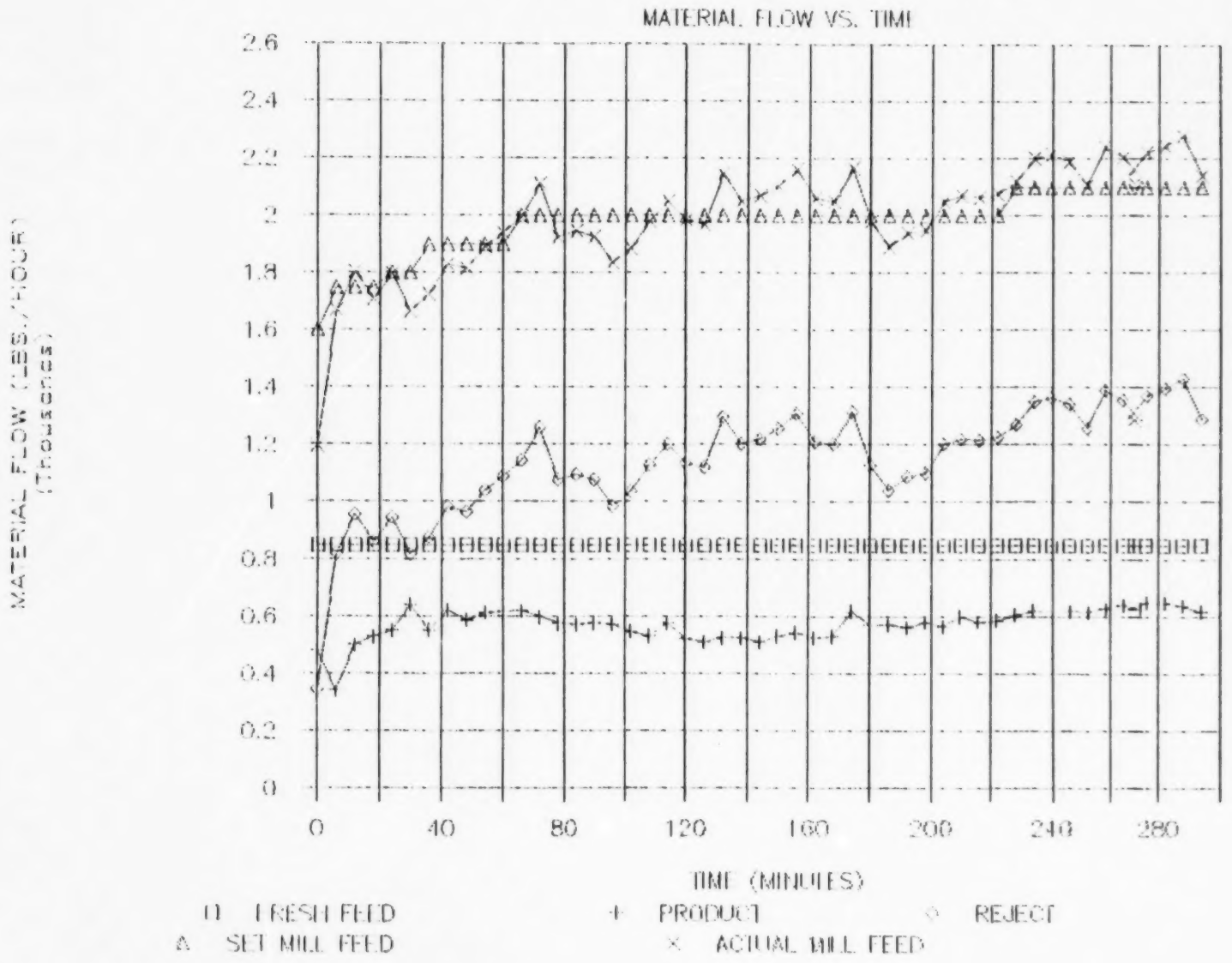
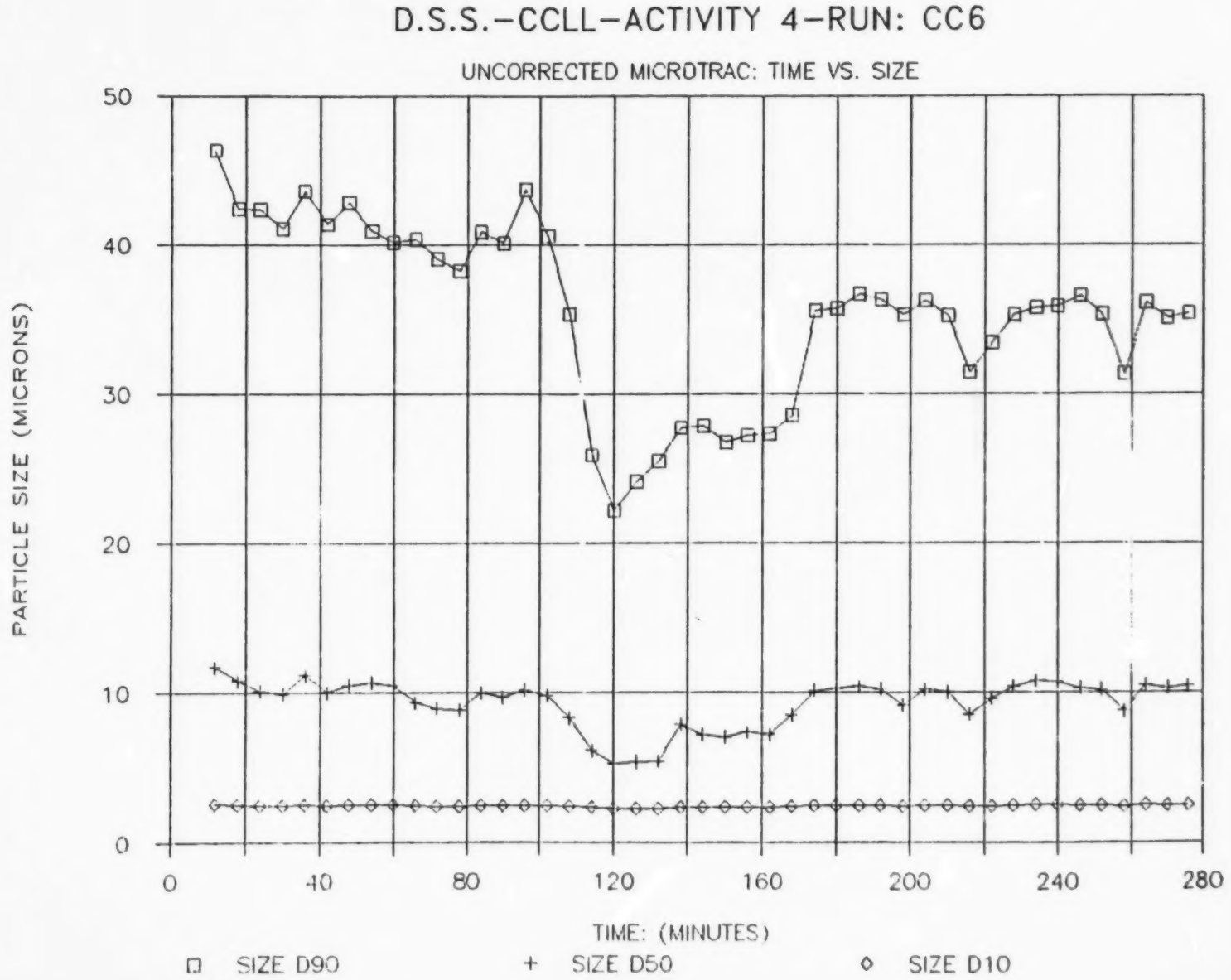
D.S.S.–CCLL–ACTIVITY 4–CC6




D.S.S.-CCLL-ACTIVITY 4-RUN: CC6
UNCORRECTED MICROTRAC: TIME VS. SIZE
PARTICLE SIZE (MICRONS)
50
40
30
20
10
0
0
40
80
120
160
200
240
280
TIME: (MINUTES)
SIZE D90
SIZE D50
SIZE D10

RUN NO. 7

Duration:	5 hours
Feed Rate:	850 lbs/hr
D_{90} Target Size:	100% passing 40 microns
Control of Circuit:	Manual, then computer controlled
Sampling:	Every 6 minutes

Circuit was started up and operated manually for one hour, then control transferred tc the computer. The rotor speed was kept constant at 750 rpm for this first hour, with a wide variation in product size. After control was passed to the computer fluctuations in product size were reduced dramatically.

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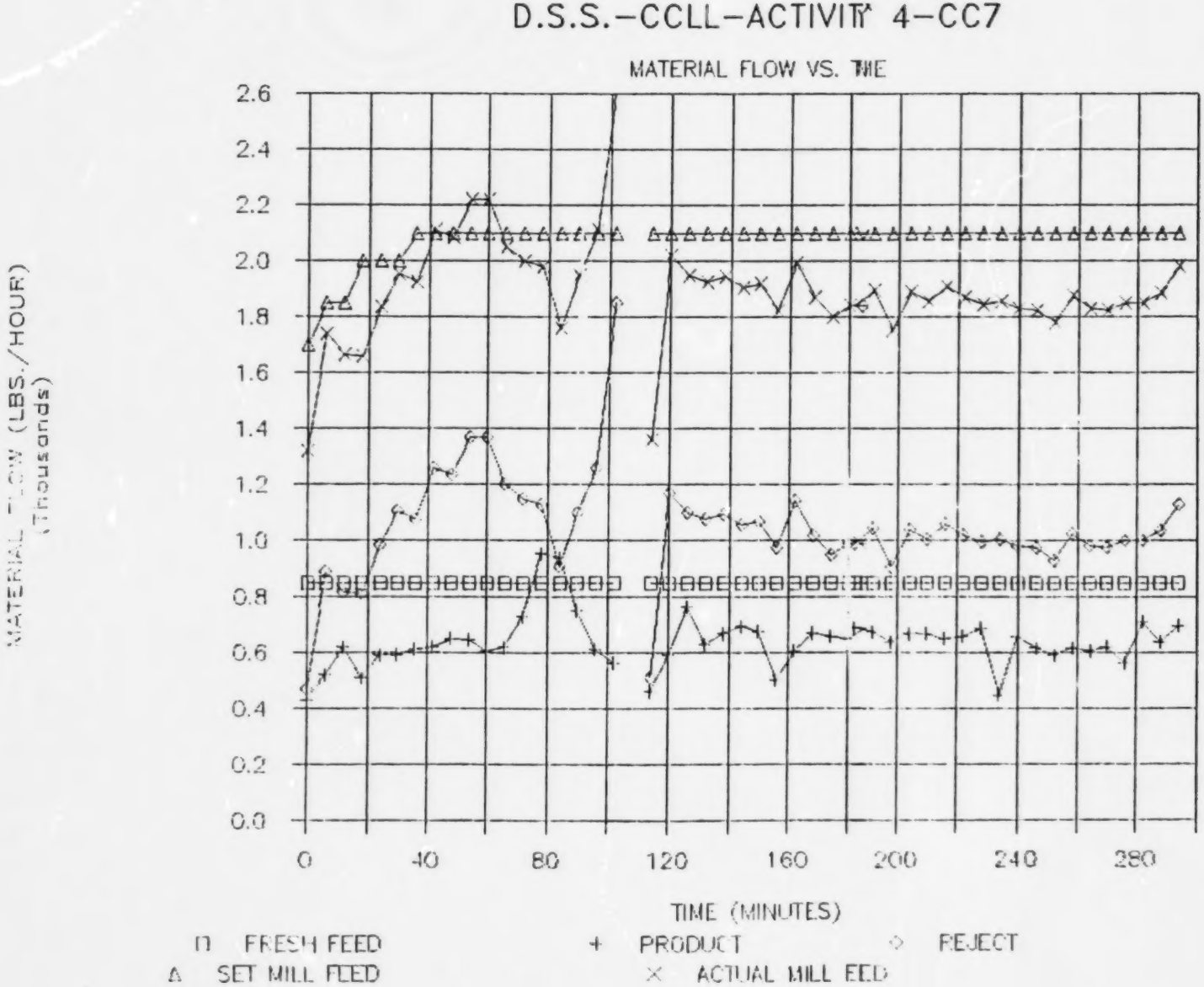
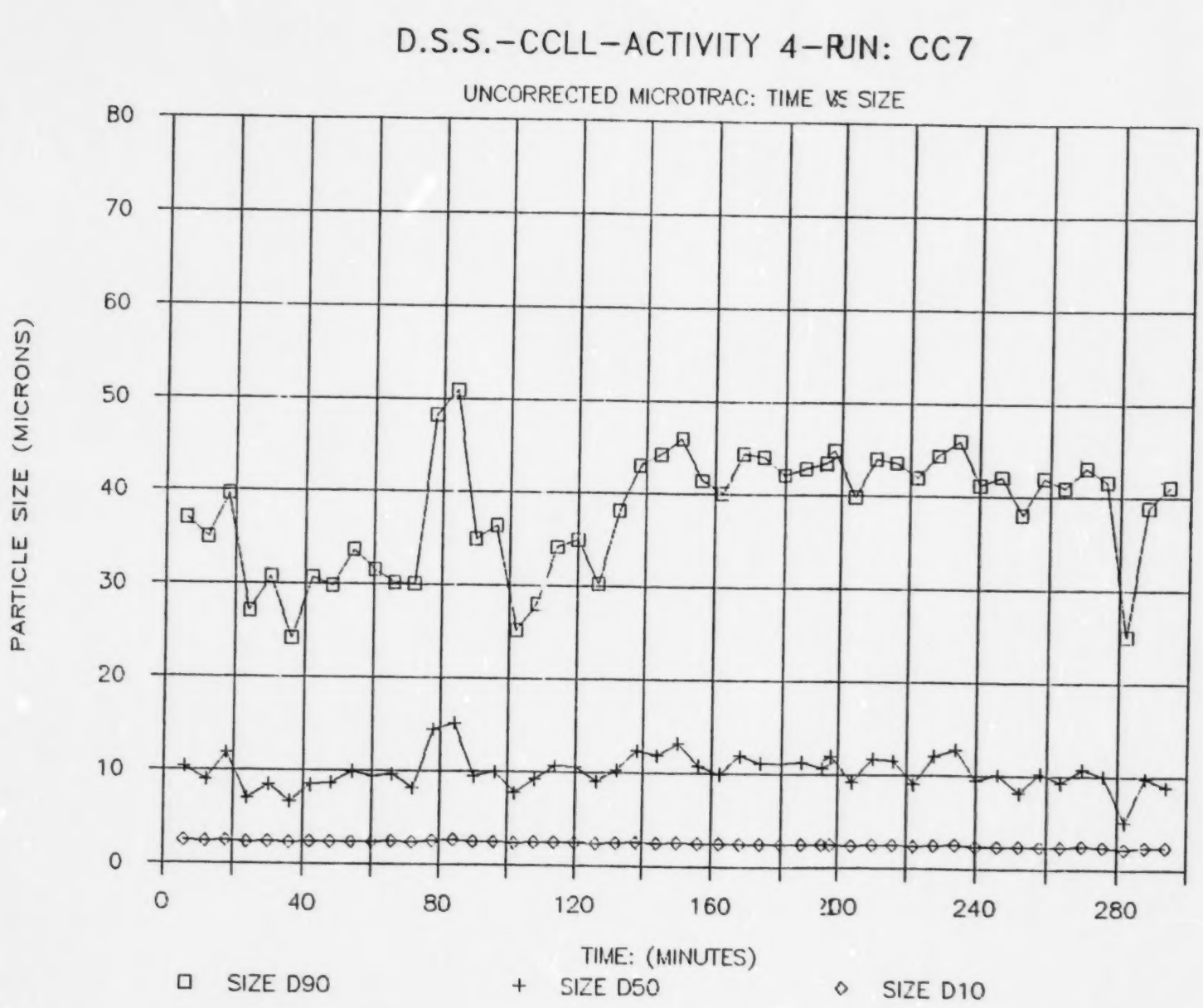

D.S.S.-CCLL-ACTIVITY 4-CC7
MATERIAL FLOW VS. TIME
MATERIAL FLOW (LBS./HOUR)
(Thousands)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
40
80
120
160
200
240
280
TIME (MINUTES)
FRESH FEED
SET MILL FEED
PRODUCT
ACTUAL MILL FEED
REJECT


D.S.S.-CCLL-ACTIVITY 4-RUN: CC7
UNCORRECTED MICROTRAC: TIME VS SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
20
10
0
0
40
80
120
160
200
240
280
TIME: (MINUTES)
SIZE D90
SIZE D50
SIZE D10

RUN NO. 8

Duration:	4 hrs 20 minutes
Feed Rate:	Variable
D_{90} Target Size:	100% 40 microns
Control of Circuit:	Computer
Sampling:	Every 6 minutes

Circuit was operated under full computer control, with the feed rate to the mill based on the output rate. This resulted in a 80 minute cycle of feed to the mill. The computer could only chase the desired feed rate, due to the time delay between circuit input and output. This resulted in a wide swing in product size.

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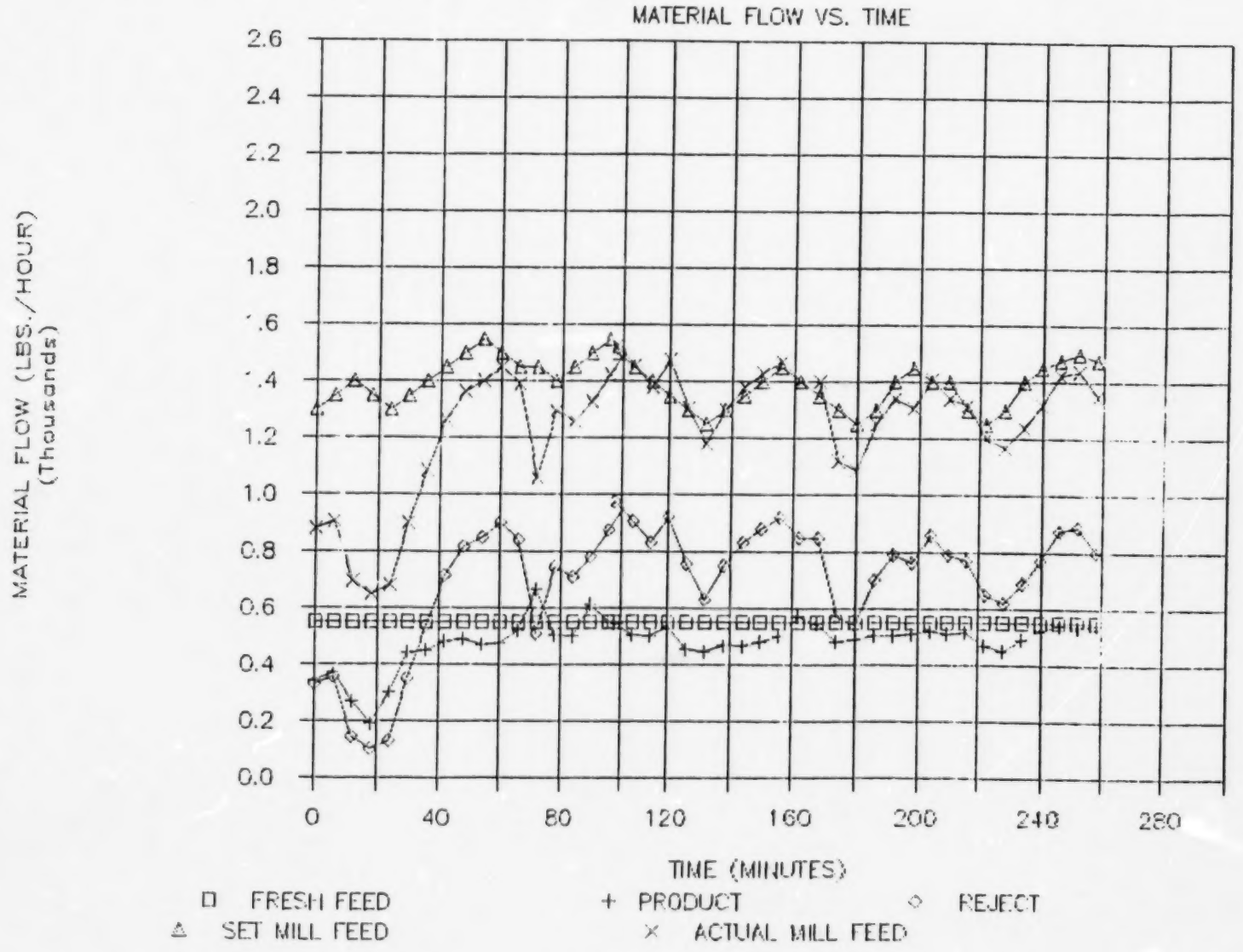
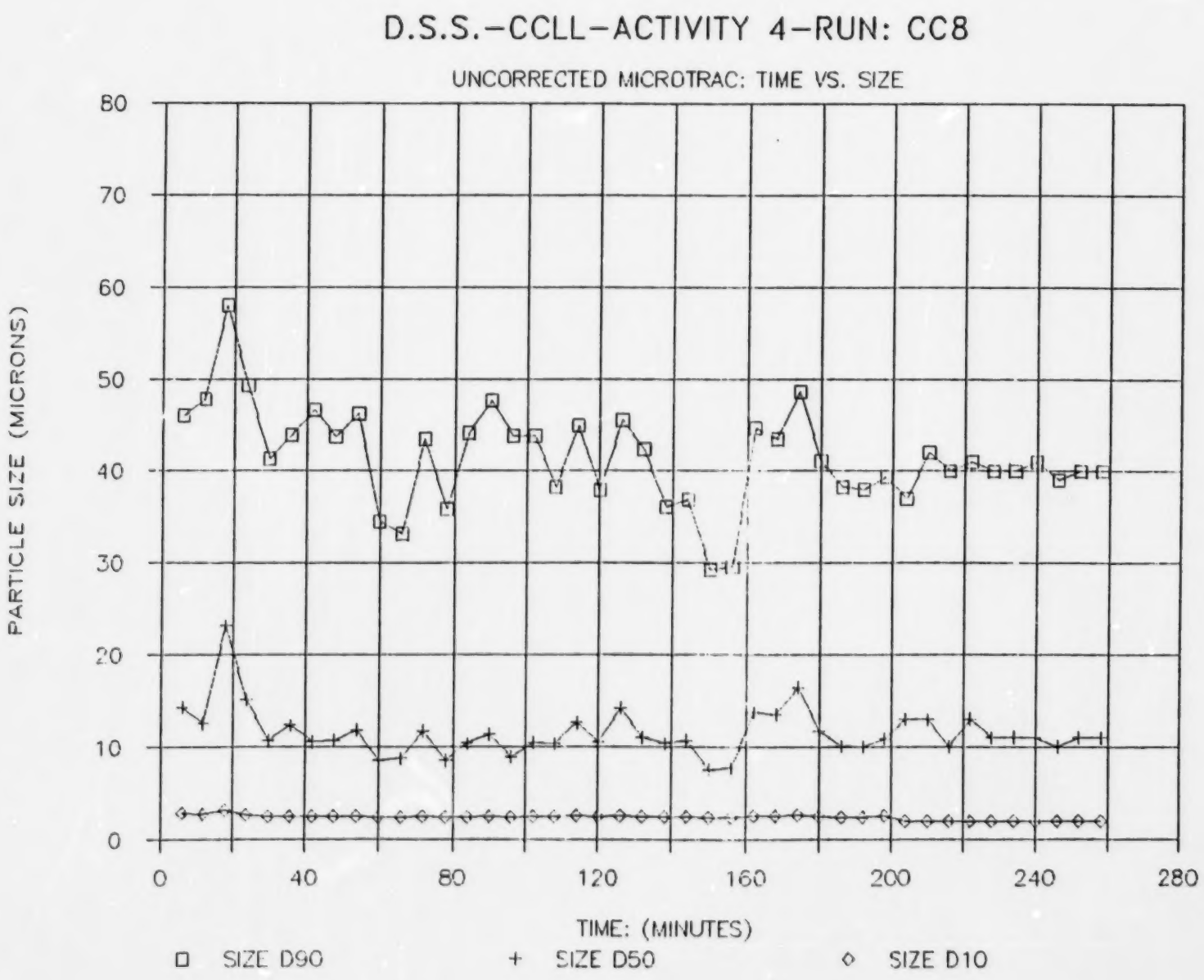
D.S.S.-CCLL-ACTIVITY 4-CC8




D.S.S.-CCLL-ACTIVITY 4-RUN: CC8
UNCORRECTED MICROTRAC: TIME VS. SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
20
10
0
0
40
80
120
160
200
240
280
TIME: (MINUTES)
SIZE D90
SIZE D50
SIZE D10

RUN NO. 9

Duration:	5 hrs 42 minutes
Feed Rate:	550 lbs/hr 30 minutes
	600 lbs/hr 30 minutes
	650 lbs/hr 60 minutes
	700 lbs/hr 66 minutes
	750 lbs/hr 54 minutes
	800 lbs/hr 60 minutes
	850 lbs/hr 42 minutes
D_{gc} Target Size:	40 micron
Control:	Computer control
Sample:	Every 6 minutes

Feed rate was steadily increased during the test from 550 lbs/hr to 850 lbs/hr. Product size was controlled exclusively by computer. It should be noted at each feed rate increase the classifier oversize drops off momentarily, then re-establishes itself at its new level.

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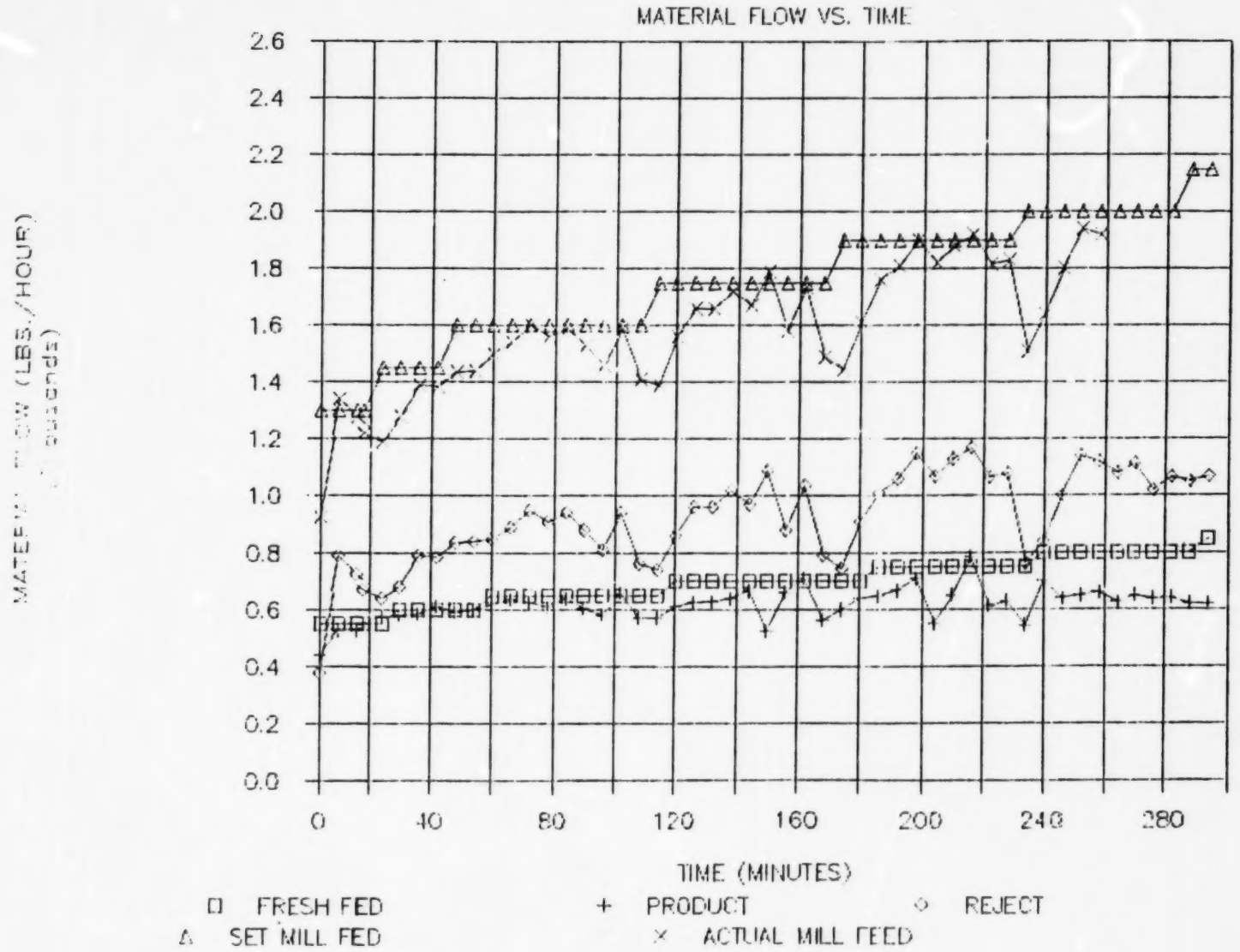
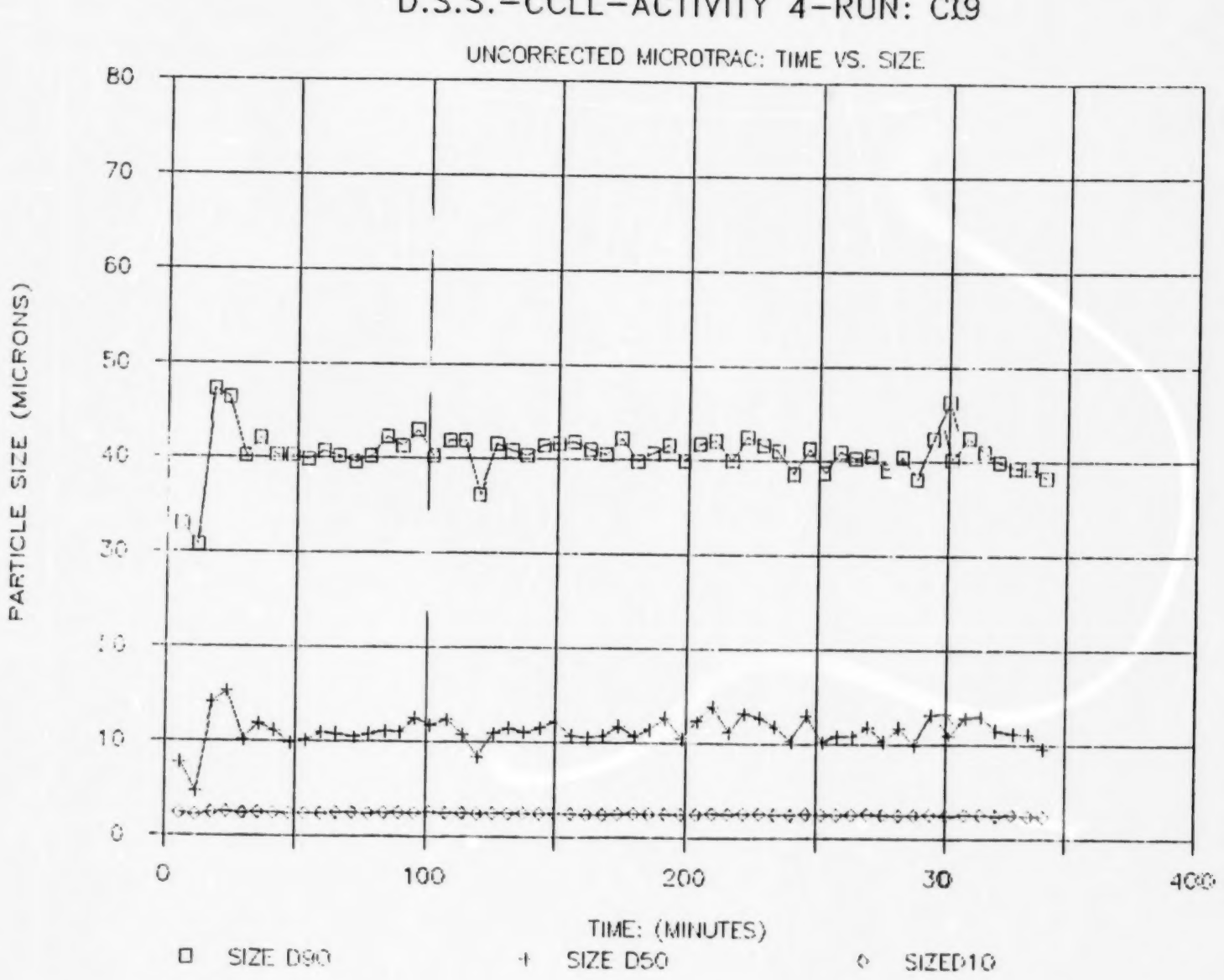
D.S.S.–CCLL–ACTIVITY 4–CC9




D.S.S.-CCLL-ACTIVITY 4-RUN: CI9
UNCORRECTED MICROTRAC: TIME VS. SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
10
0
0
100
200
300
400
TIME: (MINUTES)
SIZE D90
SIZE D50
SIZED10

RUN NO. 10

Duration:	5 hrs
Feed Rate:	650 lbs/hr 60 minutes
	700 lbs/hr 30 minutes
	750 lbs/hr 30 minutes
	800 lbs/hr 30 minutes
	850 lbs/hr 60 minutes
	600 lbs/hr 90 minutes
D_{90} Target Size:	100% pass 40 microns
Control:	Computer control
Samples:	Every 6 minutes

Feed rate was steadily increased, then returned to 600 lbs/hr from 850 lbs/hr. The circuit re-adjusted quickly to the new parameters with little effect on product quality.

CCLL ACTIVITY 4
PROJECT NO. 5174
COMPUTER CONTROLLED MILL RUN
RUN #10
SEPTEMBER 26,1986
SAMPLING FREQUENCY: EVERY 6 MINUTES

TIME (MINUTES)	FEED RATE (LBS./HR.	ROTOR SPEED (RPM)	**	MICROTRAC ANALYSIS D90	D50	D10
00:00	650	C.C.	**	40	10	2.5
00:06	650	C.C.	**	?	?	?
00:12	650	C.C.	**	?	?	?
00:18	650	C.C.	**	?	?	?
00:24	650	C.C.	**	?	?	?
00:30	650	C.C.	**	?	?	?
00:36	650	C.C.	**	?	?	?
00:42	650	C.C.	**	?	?	?
00:48	650	C.C.	**	?	?	?
00:54	650	C.C.	**	?	?	?
01:00	650	C.C.	**	?	?	?
01:06	700	C.C.	**	?	?	?
01:12	700	C.C.	**	?	?	?
01:18	700	C.C.	**	?	?	?
01:24	700	C.C.	**	?	?	?
01:30	700	C.C.	**	?	?	?
01:36	750	C.C.	**	?	?	?
01:42	750	C.C.	**	?	?	?
01:48	750	C.C.	**	?	?	?
01:54	750	C.C.	**	?	?	?
02:00	750	C.C.	**	?	?	?
02:06	800	C.C.	**	?	?	?
02:12	800	C.C.	**	?	?	?
02:18	800	C.C.	**	?	?	?
02:24	800	C.C.	**	?	?	?
02:30	800	C.C.	**	?	?	?
02:36	850	C.C.	**	?	?	?
02:42	850	C.C.	**	?	?	?
02:48	850	C.C.	**	?	?	?
02:54	850	C.C.	**	?	?	?
03:00	850	C.C.	**	?	?	?
03:06	850	C.C.	**	?	?	?
03:12	850	C.C.	**	?	?	?
03:18	850	C.C.	**	?	?	?
03:24	850	C.C.	**	?	?	?
03:30	850	C.C.	**	?	?	?
03:36	600	C.C.	**	?	?	?
03:42	600	C.C.	**	?	?	?
03:48	600	C.C.	**	?	?	?
03:54	600	C.C.	**	?	?	?
04:00	600	C.C.	**	?	?	?
04:06	600	C.C.	**	?	?	?
04:12	600	C.C.	**	?	?	?
04:18	600	C.C.	**	?	?	?
04:24	600	C.C.	**	?	?	?
04:30	600	C.C.	**	?	?	?
04:36	600	C.C.	**	?	?	?
04:42	600	C.C.	**	?	?	?
04:48	600	C.C.	**	?	?	?

05:00 600 C.C. ** ? ? ?

RAW DATA

TIME (MINUTES)	SIZE	#1 D (MICRONS)	#2 D (MICRONS)	#3 D (MICRONS)	#4 D (MICRONS)	#5 D (MICRONS)	STAN. DEV. (MICRONS)	*
00:00							0.00	*
00:06	D90	41.15	41.47	43.34	41.63	42.88	0.86	*
	D50	11.08	11.18	11.76	11.44	11.57	0.25	
	D10	2.52	2.52	2.56	2.55	2.56	0.02	
00:12	D90	43.69	42.72	46.21	43.75	46.82	1.59	*
	D50	12.68	12.08	12.33	12.62	12.7	0.24	
	D10	2.56	2.58	2.6	2.62	2.61	0.02	
00:18	D90	42.32	40.58	42.68	40.2	44.51	1.56	*
	D50	12.92	12.8	13.42	12.93	13.73	0.36	
	D10	2.65	2.62	2.67	2.63	2.65	0.02	
00:24	D90	39.89	39.4	39.58	40.03	39.35	0.27	*
	D50	11.72	11.49	11.8	11.51	11.97	0.18	
	D10	2.57	2.58	2.57	2.57	2.6	0.01	
00:30	D90	36.84	39.04	36.16			1.23	*
	D50	10.6	10.59	10.42			0.08	
	D10	2.5	2.51	2.51			0.00	
00:36	D90	36.3	36.91	35.39	36.6	36.46	0.51	*
	D50	9.83	9.85	9.84	9.97	9.88	0.05	
	D10	2.44	2.45	2.44	2.45	2.45	0.00	
00:42	D90	39.45	37.98	39.03	37.12	37.98	0.83	*
	D50	10.8	10.53	10.81	10.64	10.82	0.12	
	D10	2.48	2.48	2.49	2.49	2.5	0.01	
00:48	D90	32.79	34.78	33.19	37.2	35.59	1.61	*
	D50	9.21	9.32	9.21	9.88	9.77	0.29	
	D10	2.44	2.44	2.44	2.47	2.45	0.01	
00:54	D90	47.24	43.72	45.92	43.53	43.18	1.59	*
	D50	12.33	11.95	12.58	12.45	11.78	0.30	
	D10	2.51	2.51	2.52	2.51	2.52	0.00	
01:00	D90	39.3	40.4	41.86	41.03	39.54	0.95	*
	D50	11.65	11.37	12.19	11.64	11.73	0.27	
	D10	2.51	2.51	2.52	2.51	2.53	0.01	
01:06	D90	35.18	35.66	35.5	35.46	37.85	0.97	*
	D50	9.88	9.87	10.06	10.09	10.28	0.15	
	D10	2.43	2.42	2.44	2.43	2.48	0.02	
01:12	D90	28.87	28.72	19.12	29.2	29.27	3.96	*
	D50	6.49	6.27	6.66	6.6	6.67	0.15	
	D10	2.3	2.31	2.31	2.31	2.32	0.01	
01:18	D90	32.39	30.78	31.82	31.92	32.37	0.70	*

	D10	2.43	2.43	2.43	2.44	2.43	0.00
01:24	D90	35.98	33.19	34.88	33.82	35.1	0.98 *
	D50	10.23	9.9	10.22	10.16	10.48	0.19
	D10	2.47	2.47	2.45	2.46	2.47	0.01
01:30	D90	32.93	32.15	33.15	33.81	32.76	0.54 *
	D50	9.32	9.33	9.43	9.52	9.44	0.07
	D10	2.43	2.42	2.42	2.44	2.44	0.01
01:36	D90	30.85	30.84	32.09	32.53	32.08	0.70 *
	D50	9.41	9.31	9.32	9.52	9.58	0.11
	D10	2.44	2.44	2.44	2.44	2.44	0.00
01:42	D90	32.44	33.76	32.9	34.25	32.47	0.72 *
	D50	9.39	9.64	9.47	9.55	9.32	0.11
	D10	2.43	2.43	2.44	2.44	2.44	0.00
01:48	D90	39.32	39.46	38.27	40.14	38.55	0.67 *
	D50	11.61	12.22	11.46	11.47	11.94	0.30
	D10	2.53	2.52	2.51	2.51	2.54	0.01
01:54	D90	32.72	37.72	34.22	35.19	34.78	1.63 *
	D50	9.88	10.31	10.02	10.3	10.31	0.18
	D10	2.47	2.49	2.48	2.47	2.5	0.01
02:00	D90	33.8	36.05	32.94	33.68	34.59	1.06 *
	D50	9.2	9.41	9.12	9.23	9.28	0.10
	D10	2.43	2.44	2.43	2.43	2.43	0.00
02:06	D90	29.53	29.28	29.19	28.89	29.18	0.21 *
	D50	6.97	6.89	6.78	6.83	6.68	0.10
	D10	2.33	2.33	2.33	2.33	2.33	0.00
02:12	D90	33.96	34.35	34.71	33.58	35.01	0.51 *
	D50	10.13	10.02	10.28	10.15	10.35	0.12
	D10	2.47	2.48	2.46	2.48	2.48	0.01
02:18	D90	35.76	35.36	36.41	36.23	37.31	0.66 *
	D50	10.08	10.13	10.34	10.29	10.52	0.16
	D10	2.45	2.46	2.46	2.47	2.48	0.01
02:24	D90	38.28	35.11	36.23	37.02	37.43	1.08 *
	D50	10.46	10.18	10.53	10.27	10.39	0.13
	D10	2.47	2.47	2.47	2.48	2.5	0.01
02:30	D90	37.05	37.63	36.8	38.05	39.51	0.96 *
	D50	10.79	10.72	10.92	11.19	11.54	0.30
	D10	2.49	2.5	2.48	2.49	2.5	0.01
02:36	D90	39.85	41.47	39.45	40.68	40.91	0.73 *
	D50	12.73	13.06	13.02	12.84	13.09	0.14
	D10	2.57	2.55	2.58	2.57	2.59	0.01
02:42	D90	37.22	35.32	35.45	37.54	37.38	0.98 *
	D50	10.47	10.32	10.35	10.64	10.33	0.12
	D10	2.47	2.47	2.47	2.47	2.5	0.01
02:48	D90	31.64	33.93	31.84	33.21	33.92	0.99 *

	D10	2.5	2.52	2.51	2.52	2.5	0.01
02:54	D90	32.85	33.61	31.99	31.98	34.88	1.09 *
	D50	9.98	10	9.93	10.12	10.27	0.12
	D10	2.49	2.5	2.49	2.5	2.5	0.00
03:00	D90	30.63	30.83	29.69	30.9	30.32	0.44 *
	D50	8.66	8.7	8.53	8.76	8.71	0.08
	D10	2.41	2.41	2.41	2.42	2.43	0.01
03:06	D90	38.2	36.87	36.27	36.56	35.94	0.78 *
	D50	10.72	10.82	10.58	10.64	10.47	0.12
	D10	2.55	2.5	2.52	2.51	2.52	0.02
03:12	D90	37.81	35.71	35.42	37.84	36.64	1.02 *
	D50	11.11	11.08	10.76	11.47	11.3	0.24
	D10	2.54	2.53	2.55	2.53	2.52	0.01
03:18	D90	37.13	36.58	39.68	37.28	39.46	1.28 *
	D50	10.92	10.72	11.19	11.39	10.9	0.24
	D10	2.53	2.51	2.51	2.51	2.53	0.01
03:24	D90	41.96	41.94	40.46	40.85	42.25	0.70 *
	D50	12.91	13.1	12.94	13.02	13.14	0.09
	D10	2.57	2.58	2.57	2.57	2.6	0.01
03:30	D90	42.85	44.95	41.64	41.77	41.24	1.34 *
	D50	12.97	12.78	12.99	12.84	12.58	0.15
	D10	2.55	2.57	2.57	2.56	2.54	0.01
03:36	D90	34.57	36.51	35.66	35.36	36.85	0.82 *
	D50	10.02	9.79	9.87	10.04	10.15	0.13
	D10	2.46	2.46	2.46	2.45	2.46	0.00
03:42	D90	35.68	36.22	37.66	36.6	36.88	0.66 *
	D50	10.51	10.44	10.54	10.48	10.58	0.05
	D10	2.47	2.46	2.49	2.47	2.48	0.01
03:48	D90	36.37	35.44	35	34.74	36.58	0.73 *
	D50	10.25	10.26	10.24	10.27	10.52	0.11
	D10	2.47	2.47	2.45	2.47	2.47	0.01
03:54	D90	30.8	30.91	30.56	30.55	32.44	0.71 *
	D50	8.26	8.29	8.21	8.31	8.49	0.10
	D10	2.39	2.39	2.38	2.39	2.4	0.01
04:00	D90	36.1	36.57	37.73	36.51	35.83	0.65 *
	D50	9.81	9.77	10.02	10.02	9.76	0.12
	D10	2.43	2.44	2.45	2.43	2.44	0.01
04:06	D90	36.53	35.49	35.5	36.13	37.31	0.68 *
	D50	9.84	9.8	9.76	9.97	9.83	0.07
	D10	2.43	2.43	2.45	2.45	2.46	0.01
04:12	D90	33.52	34.41	34.08	34.01	34.45	0.34 *
	D50	9.51	9.45	9.49	9.53	9.64	0.06
	D10	2.41	2.42	2.41	2.41	2.43	0.01
04:18	D90	33.65	34.61	33.08	33.81	33.17	0.55 *

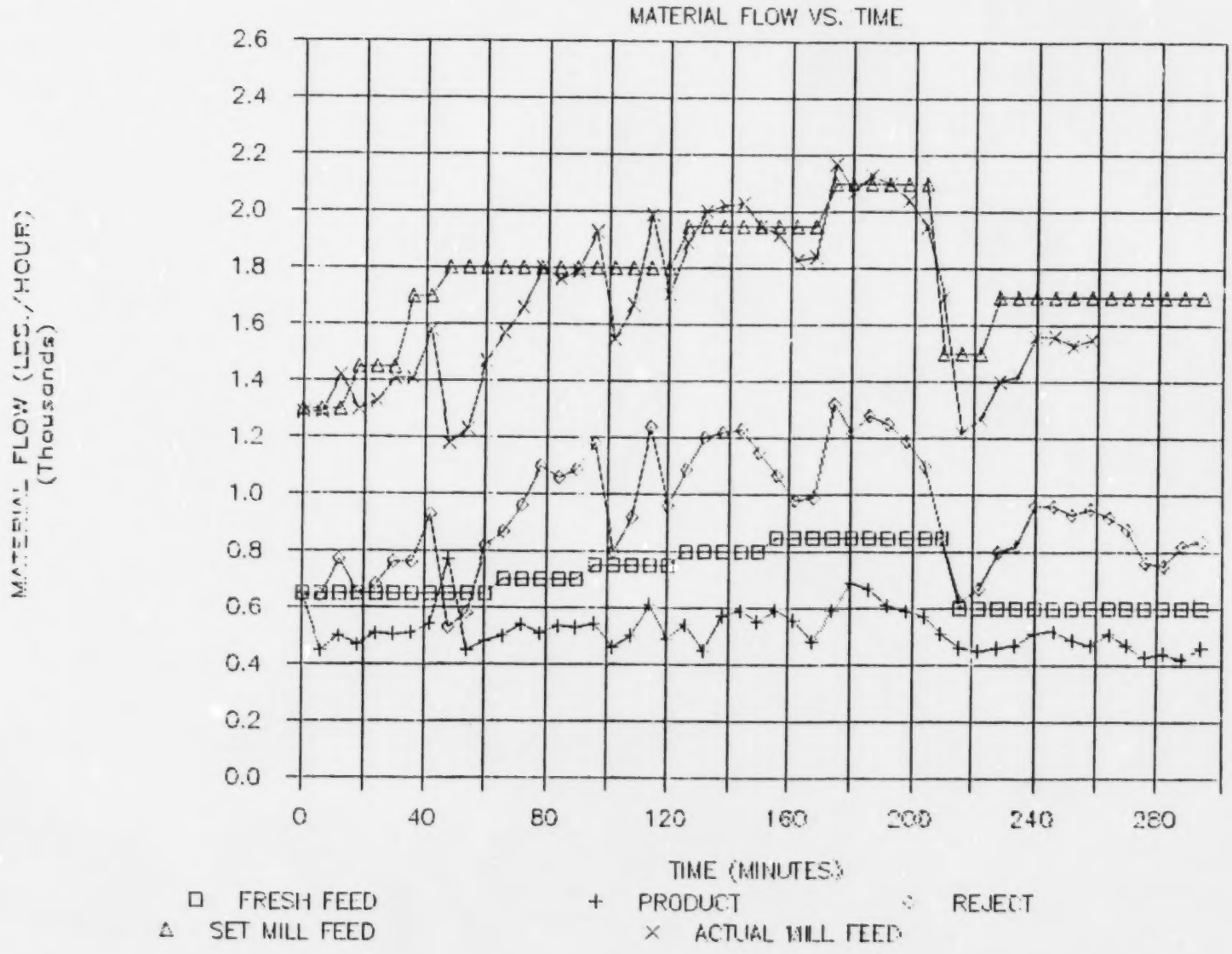
	D10	2.41	2.41	2.4	2.42	2.4	0.01	
04:24	D90	39.95	39.14	40.61	39.71	40.48	0.53	*
	D50	10.97	10.95	11.28	11.17	11.04	0.13	
	D10	2.44	2.45	2.47	2.47	2.46	0.01	
04:30	D90	36.26	36.76	37.36	36.47	37.51	0.49	*
	D50	9.07	9.14	9.26	9.42	9.43	0.14	
	D10	2.4	2.4	2.4	2.39	2.42	0.01	
04:36	D90	34.86	34.62	33.33	34.15	33.65	0.57	*
	D50	8.77	8.68	8.63	8.66	8.61	0.06	
	D10	2.36	2.35	2.36	2.36	2.35	0.00	
04:42	D90	35.85	36.07	35.43	34.76	36.12	0.51	*
	D50	9.81	9.85	9.78	9.78	9.72	0.04	
	D10	2.41	2.41	2.41	2.41	2.41	0.00	
04:48	D90	32.39	31.86	33.79	31.5	32.21	0.78	*
	D50	8.59	8.58	8.86	8.55	8.67	0.11	
	D10	2.4	2.4	2.4	2.4	2.41	0.00	
04:54	D90						ERR	*
	D50							
	D10							
05:00	D90						ERR	*
	D50							
	D10							

ACTUAL OPERATION

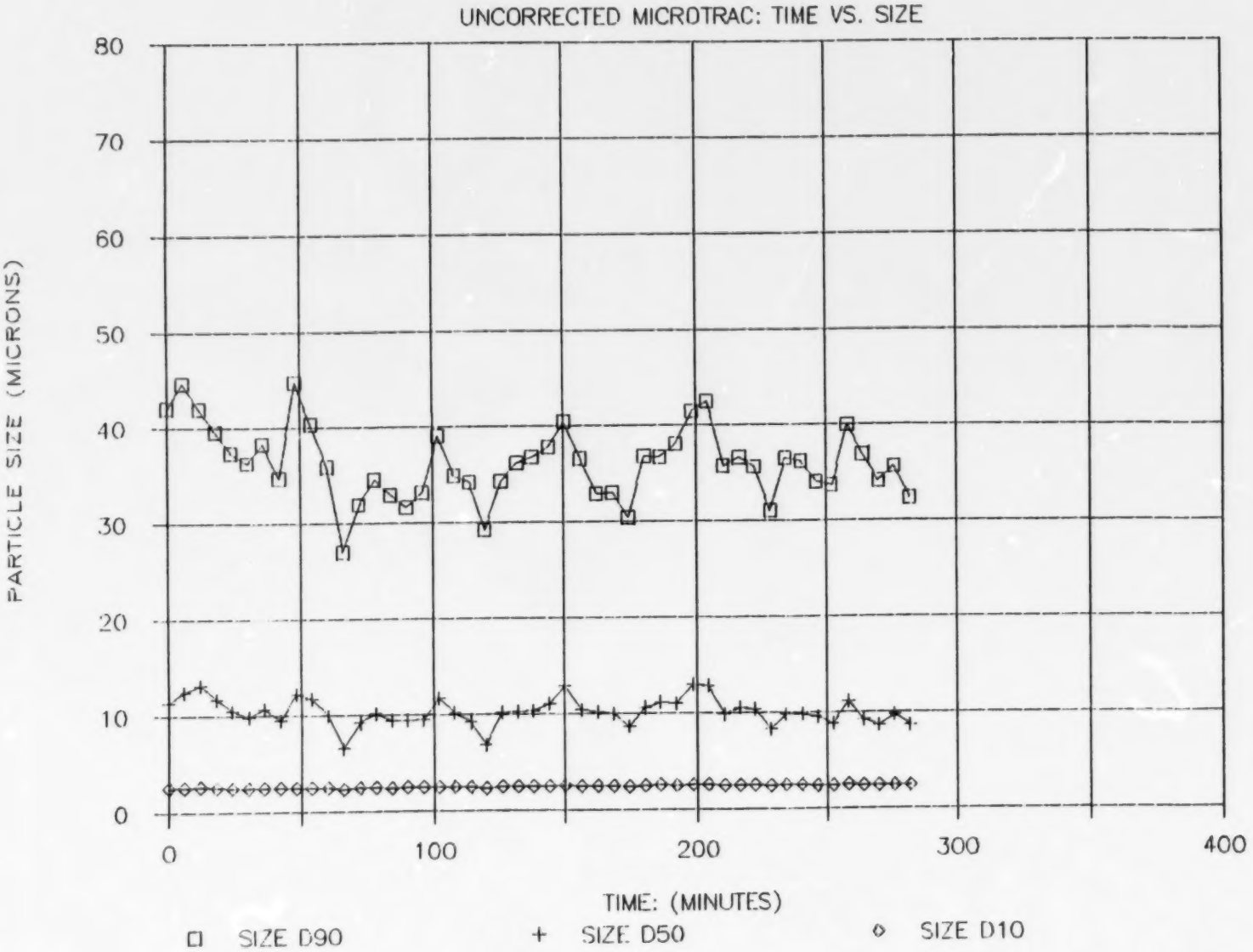
TIME (MINUTES)	FEED RATE (LBS/HR.)	ROTOR SPEED (RPM)	AVERAGE D90 (MICRONS)	MICROTRAC AVERAGE D50 (MICRONS)	ANALYSIS AVERAGE D10 (MICRONS)
0	650				
6	650		42.1	11.4	2.5
12	650		44.6	12.5	2.6
18	650		42.1	13.2	2.6
24	650		39.7	11.7	2.6
30	650		37.3	10.5	2.5
36	650		36.3	9.9	2.4
42	650		38.3	10.7	2.5
48	650		34.7	9.5	2.4
54	650		44.7	12.2	2.5
60	650		40.4	11.7	2.5
66	700		35.9	10.0	2.4
72	700		27.0	6.5	2.3
78	700		32.0	9.3	2.4
84	700		34.6	10.2	2.5
90	700		33.0	9.4	2.4
96	750		31.7	9.4	2.4
102	750		33.2	9.5	2.4
108	750		39.1	11.7	2.5
114	750		34.9	10.2	2.5
120	750		34.2	9.2	2.4

132	800	**	34.3	10.2	2.5	**
138	800	**	36.2	10.3	2.5	**
144	800	**	36.8	10.4	2.5	**
150	800	**	37.8	11.0	2.5	**
156	850	**	40.5	12.9	2.6	**
162	850	**	36.6	10.4	2.5	**
168	850	**	32.9	10.2	2.5	**
174	850	**	33.1	10.1	2.5	**
180	850	**	30.5	8.7	2.4	**
186	850	**	36.8	10.6	2.5	**
192	850	**	36.7	11.1	2.5	**
198	850	**	38.0	11.0	2.5	**
204	850	**	41.5	13.0	2.6	**
210	850	**	42.5	12.8	2.6	**
216	600	**	35.8	10.0	2.5	**
222	600	**	36.6	10.5	2.5	**
228	600	**	35.6	10.3	2.5	**
234	600	**	31.1	8.3	2.4	**
240	600	**	36.5	9.9	2.4	**
246	600	**	36.2	9.8	2.4	**
252	600	**	34.1	9.5	2.4	**
258	600	**	33.7	8.8	2.4	**
264	600	**	40.0	11.1	2.5	**
270	600	**	36.9	9.3	2.4	**
276	600	**	34.1	8.7	2.4	**
282	600	**	35.6	9.8	2.4	**
288	600	**	32.4	8.7	2.4	**
294	600	**				**
300	600	**				**
AVERAGE			36.2	10.5	2.6	

D.S.S.–CCLL–ACTIVITY 4–CC10



D.S.S.-CCLL-ACTIVITY 4-RUN: CC10



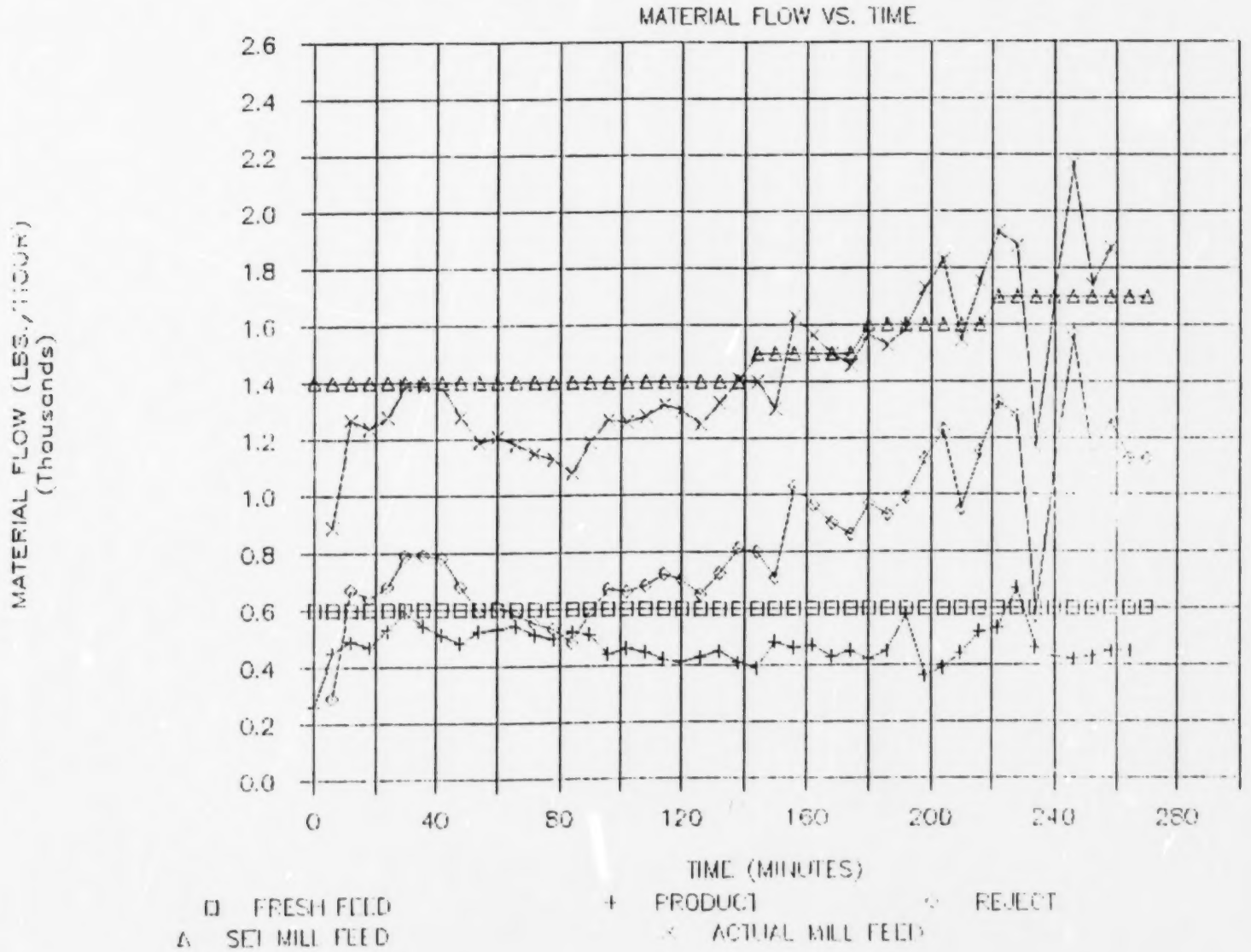
RUN NO. 11

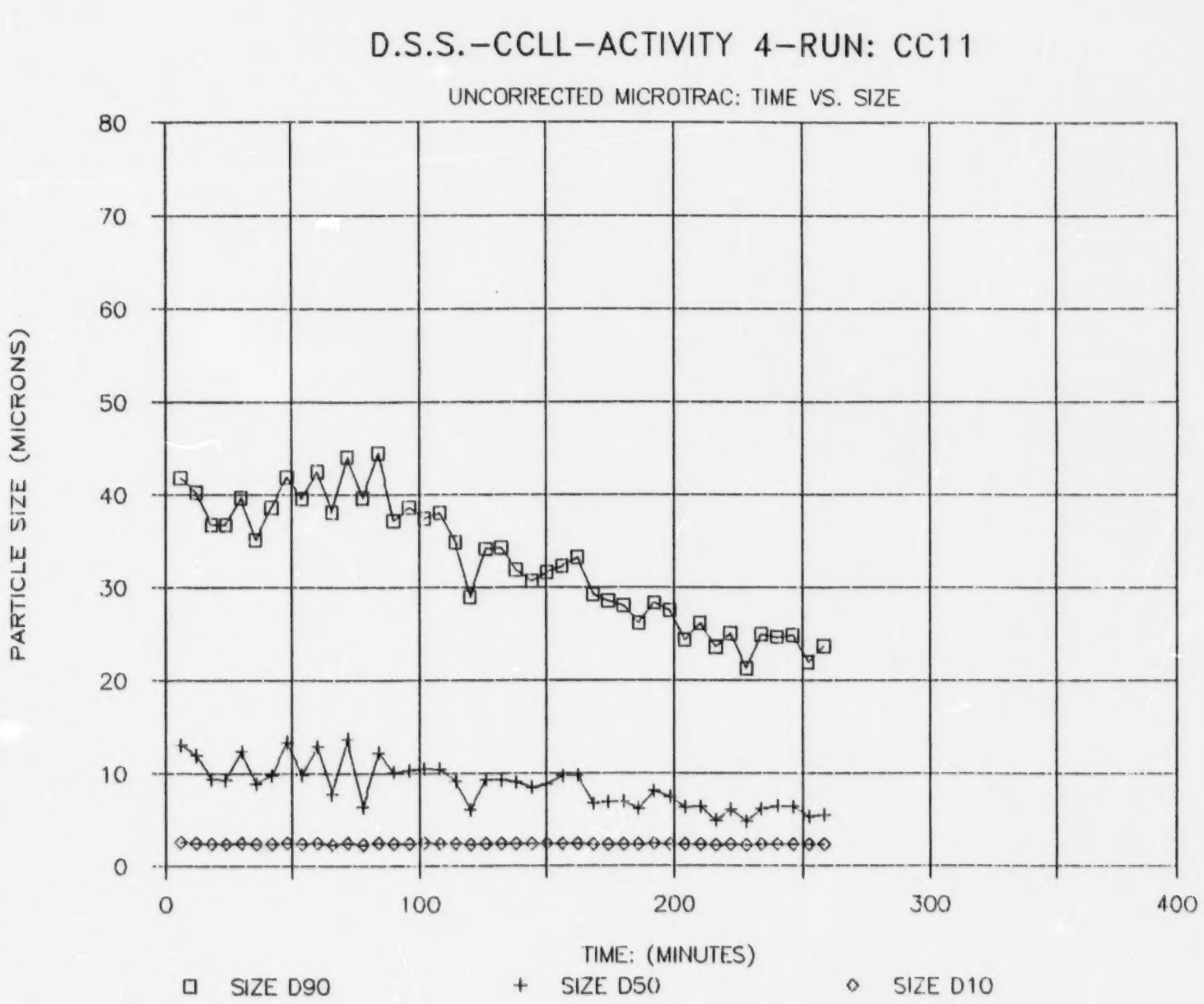
Duration:	4 hrs 30 minutes
Feed Rate:	600 lbs/hr
D_{90} Target Size:	40 microns
	30 microns
	20 microns
Control:	Computer control
Sampling:	Every 6 minutes

Circuit ran smoothly under computer control for full length of test. Circuit established new equilibrium quickly after a change in product specifications.

WD1

D.S.S.-CCLL-ACTIVITY 4-CC11




D.S.S.-CCLL-ACTIVITY 4-RUN: CC11
UNCORRECTED MICROTRAC: TIME VS. SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
20
10
0
0
100
200
300
400
TIME: (MINUTES)
SIZE D90
SIZE D50
SIZE D10

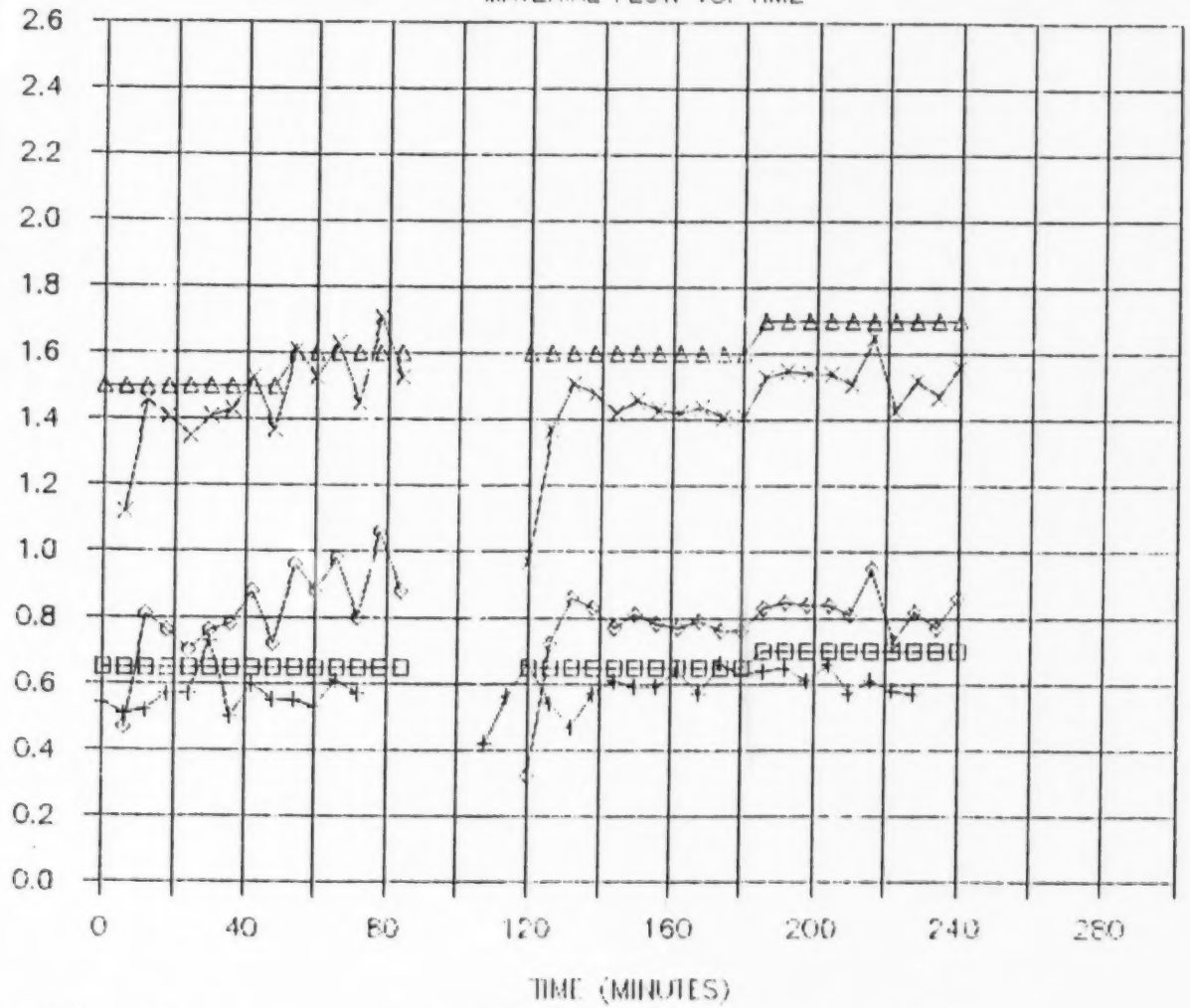
RUN NO. 12

Duration:	4 hours
Feed Rate:	650 lbs/hr 2.5 hours
	700 lbs/hr 1 hour
	0 lbs/hr 0.5 hours
D_{90} Target Size:	100% 40 microns
Control:	Computer control
Sampling:	Every 6 minutes

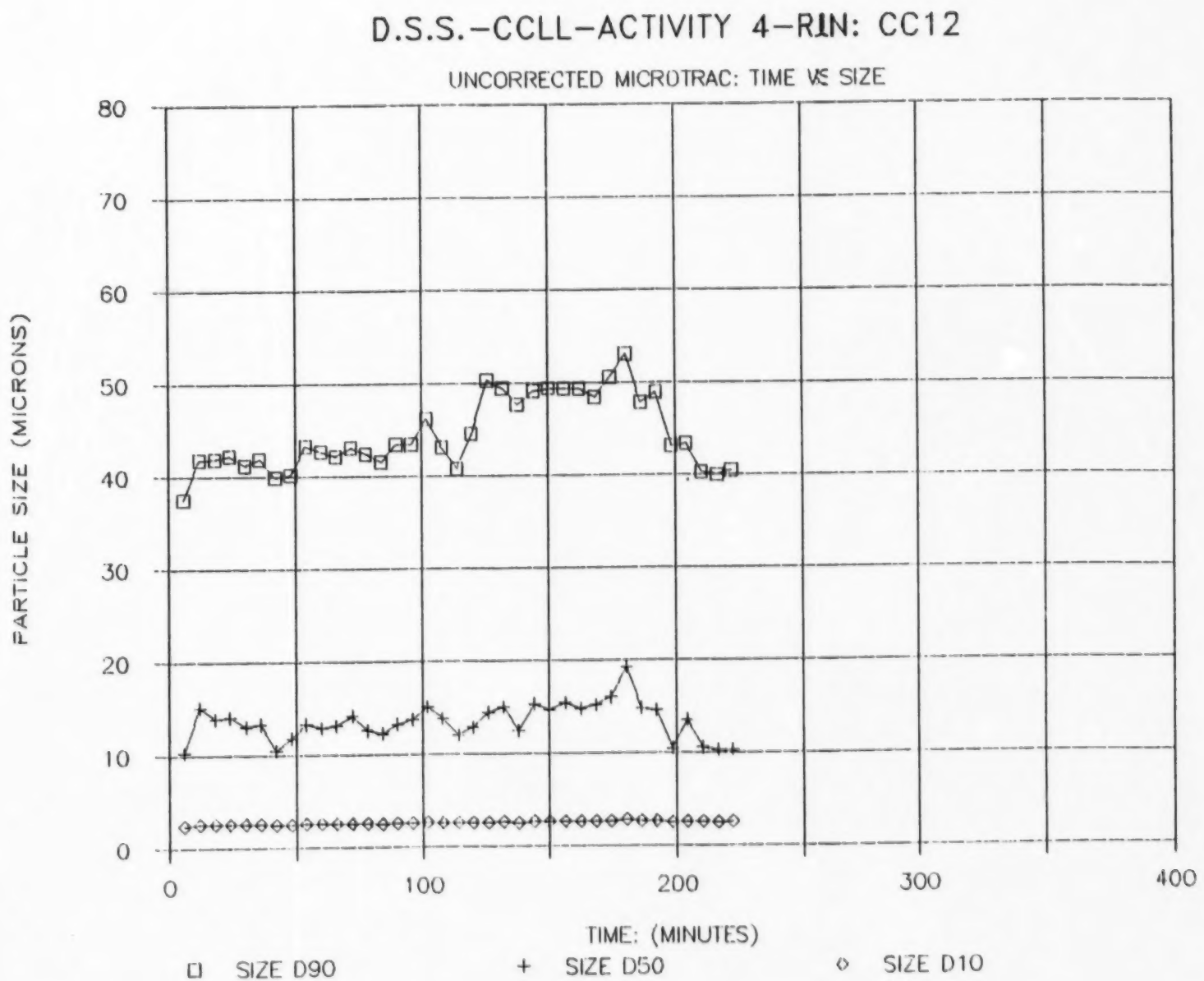
This test was run to observe the time required for the computer to re-establish equilibrium after a circuit upset, such as a prolonged shutdown. It was observed that an upset such as a 30 minute shutdown had little effect on the time required to bring product quality up to specification with computer control.

D.S.S.–CCLL–ACTIVITY 4–CC12

MATERIAL FLOW VS. TIME



CCLL ACTIVITY 4
PROJECT NO. 5174
MATERIAL FLOW
C.C. MILL RUN NO. 12
DATE: OCTOBER 6, 1986


D.S.S.-CCLL-ACTIVITY 4-RUN: CC12
UNCORRECTED MICROTRAC: TIME VS SIZE
PARTICLE SIZE (MICRONS)
80
70
60
50
40
30
20
10
0
0
100
200
300
400
TIME: (MINUTES)
SIZE D90
SIZE D50
SIZE D10

CONCLUSIONS

Based on the pilot plant testing completed during Activity 1 and 4, the following conclusions have been determined:

1. Replacing a conventional classifier with a properly sized high efficiency classifier may improve the following:

   - Average power savings in comminution: 25%
   - Increase in classifier efficiency: 32%
   - Increase in production rate: 74%

2. The Microtrac particle size analyzer is not suitable for dry analysis of calcite for the following reasons:

   - Calcite is a refractory material
   - Microtrac dry sampling system is susceptible to plugging under humid conditions
   - Particle agglomeration occurs during sample feed and transport to the sample cell.

3. The Microtrac particle size analyzer is suitable for wet anlysis of calcite for the following reasons:

   - Good repeatability of results in specific size ranges
   - Accurate when correction factors are used in conjunction with separate computer
   - Quick sampling and analysis time

4. Off-line particle size analysis is useful to a mill operator in monitoring and controlling the performance of the milling and classification circuit.

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5. On-line particle size analysis and computer control of the milling and classification circuit is beneficial to the operation as follows:

- Increase in classification efficiency 8 - 10%
- Increase in production rate 15 - 25%

- Maintain energy demand with increased classification efficiency and production rate.

- Decrease operator error and decision making input

- Maintain constant product size distribution

- Reduce production of off-spec. product during change-over and up-set conditions

- Decrease operating costs by:

  - 20 to 25% (High efficiency classifier circuit)

  - 25 to 50% (Conventional circuit up-graded with high efficiency classifier, on-line particle size analysis and computer control)

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